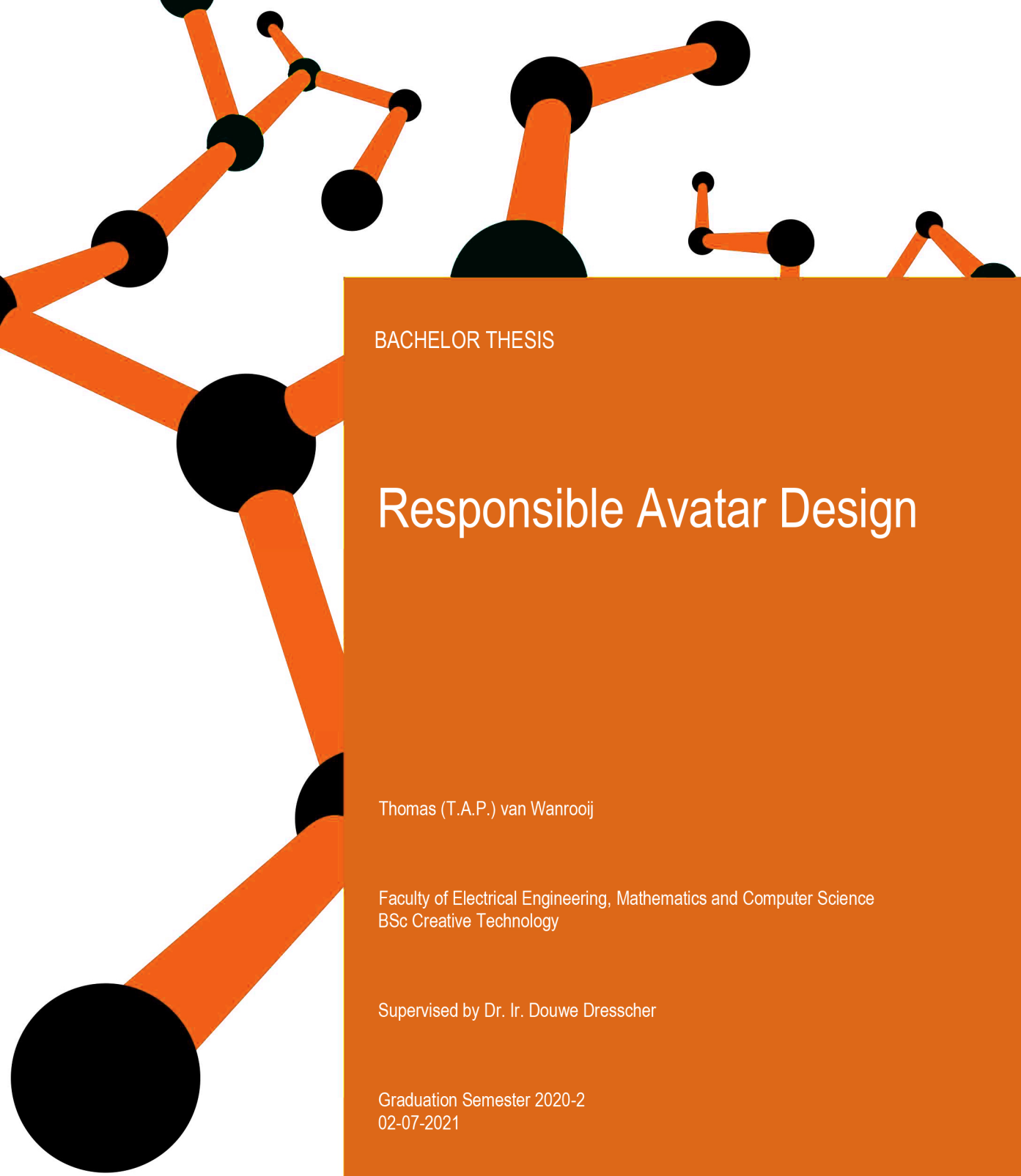

BACHELOR THESIS

Responsible Avatar Design

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ABSTRACT

The progression on Avatar Robots, which allow for telepresence and telemanipulation, promises a widespread positive impact. Such technology can be paramount to reaching the Sustainable Development Goals (SDG's). However, it cannot be taken for granted that good intentions create only positive impact. For this reason, this study aims to create an overview of the impact on society of Avatar Robots in both opportunities as well as the threats (ethical concerns) – through the impact on (sub) SDG's –that arise to reach the envisioned positive impact while avoiding the pitfalls.

A start towards this overview is made through the combination of a technology-driven and an impact-driven approach. The technology-driven approach is a literature-based analysis of direct impact of Avatar Robot applications and concerns on the SDG's. The impact-driven approach is a new brainstorm session. It is held to create scenarios of how Avatar Robots play a role in achieving the top five most catalytic sub-SDG's. The results of these two approaches are combined in a comprehensive diagram that visualises the additional input realized by introduction of the impact-driven approach. This new approach of investigating impact is presented as a fruitful starting point towards a broad, multi-perspective overview of the impact of Avatar Robots on society.

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1 INTRODUCTION

This research concerns the development of Avatar Robots. This is a technology that allows for telepresence (remote presence) and telemanipulation (remote handling). The best term to describe this remote presence is 'embodiment of a robot' in another place. This embodiment allows for physical presence and interaction in remote locations. Being 'embodied' means that the operator or 'visitor' to the remote place is in a virtual reality system that receives sensory data (vision, sound, touch) from the sensors of the remote robot, so that the operator sees, hears and feels from the cameras (eyes), microphones (ears) and touch sensors on the remote robot [1].

The progression on Avatar Robots promises a widespread positive impact. Such technology can be paramount to reaching the Sustainable Development Goals (SDG's). This is achieved through a multitude of applications for Avatar Robots including: Reducing the need for transportation resulting in reduced emissions, no longer requiring people to be physically present in hazardous and dangerous situations and reducing the time caretakers must spend travelling, thus increasing the time available to spend with patients. This positive impact is desirable in our future society.

However, it cannot be taken for granted that good intentions create only positive impact. This can also be seen in the report on Augmented Reality (AR) by the Rathenau Institute [2]. Therefore, it is relevant to gain insight in the threats that can arise. For this reason, an overview must be created of the impact on society of Avatar Robots in both opportunities as well as the threats (ethical concerns) – through the impact on (sub) SDG's – that arise to reach the envisioned positive impact while avoiding the pitfalls.

Furthermore, it is acknowledged that short term impact is necessary to keep R&D going. However, it is also imperative to take long-term goals and impact into account in the early phases. These goals should be used as design principles in the beginning, as it may be disproportionally difficult to change the product at a later stage.

For this reason, the goal of this paper is to create a broad overview of the impact that can be created through Avatar Robots. In an effort to create this overview, an investigation is made of the short- and mid-term applications of Avatar Robots and their direct impact, both positive and negative. This will be done through a literature analysis of applications and ethical concerns, and an analysis of the direct impact on the SDG's. Additionally, we will do

an explorative investigation of long-term goals of Avatar Robots, through a brainstorm with experts.

Finally, in the discussion we pull the insights together in a combined overview of both the direct and indirect impact that can be created through Avatar Robots. The overview shines a light on both positive and negative impact and both short term and long-term impact. With this overview, this paper positions itself as a starting point for responsible Avatar design, which is designed to spark a movement towards a broader perspective on responsible development of Avatar Robots.

2 BACKGROUND RESEARCH

In this section, an investigation is made of the state of the art of Avatar Robot applications as well as the ethical concerns that are tied to this technology. Based on this information, we analysis the direct impact of Avatar Robots. In this case, current and near-future applications are referenced with the SDG's. This is the first step towards a systemic overview of the impact of Avatar Robots.

2.1 Definition

An Avatar Robot is a robot system that can be used for telepresence (remote presence). The best term to describe this remote presence is 'embodiment of a robot' in another place. This embodiment allows for physical presence and interaction in remote locations. Being 'embodied' means that the operator or 'visitor' to the remote place is in a virtual reality system that receives sensory data (vision, sound, touch) from the sensors of the remote robot, so that the operator sees, hears and feels from the cameras (eyes), microphones (ears) and touch sensors on the remote robot [1]. What is not mentioned in this article but is crucial to make the experience feasible and pleasant, is the importance of low delay. It is argued in [3] that it is imperative for this visitor's perception of the remote location to be as realistic and as real-time as possible. Only then the effect can be created where the robot body can be experienced as if it were their own body. Furthermore, especially in fine motoric movement, it is imperative that latency is low, and the sensory data is high definition. For example, in telesurgery, studies have indicated that more latency reduces operator performance and are associated with more errors [3]. Although this example is specific to remote surgery, its theory can be applied to all applications which require precise movements. Overall, it may be said that an Avatar Robot is a system that enables remote presence and remote handling through a virtual environment that represents the remote location to the operator in real-time. It does not require much imagination that such a promising and slightly futuristic feat of technology can bring many possibilities for applications. Therefore, in the following section an investigation will be made of applications of Avatar Robots. This will help create an understanding of the societal impact that can be generated by Avatar Robots.

2.2 Applications

In this section, an overview is presented of various applications of Avatar Robots. In particular, [4] provides interesting insights in the applications of Avatar Robots in various disciplines such as (informal) care, safety and education. In the later stages of this research, this technology driven analysis of Avatar Robot applications will be compared to an impact-driven approach.

2.2.1 Dangerous jobs

It is already commonplace for simple, repetitive physical labour to be replaced by automated, autonomous robot systems. This is evident in the report of [5], where an analysis concludes that adoption of automation is highest in repetitive, low-supervision physical labour. In contrast, more complex physical work still requires human supervision or intervention. As a result, this can require people to be in dangerous places. To improve human safety, a logical avenue for development to be pursued is ways to get humans out of dangerous.

Already, there are examples [6] where firefighters and other first responders are relieved by robots in extinguishing fires, where robots provide injured with first aid and/or guide them out of dangerous areas. In these examples, these robots have more simple shapes. If these robots are Avatar Robots, an expertly trained firefighter could provide assistance and guidance from a remote location in a more human-like way.

Another example of a dangerous situation that humans still have to work in, is the operation of switches in industrial settings. This can lead to exposure to an arc flash, a high incident energy fault, to technicians operating low and medium voltage switching equipment [7]. Due to the critical nature of this operation, it cannot be automated in the way regular industrial mechanics can be automated. Therefore, these currently have to be manually operated by a human in a bomb suit. In the case an engineer can remotely operate this switch through a teleoperated robot their safety can be guaranteed.

Additionally, off-shore wind energy is one of the fastest-growing energy sources in the world, but the exploitation of renewable energy imposes a number of technical challenges [4]. The first is that these stations need highly specific electrical and mechanical equipment. To avoid failure of these systems, regular inspection by human operators is a necessity. However, it is very costly for the companies, and dangerous for the employees to have these platforms manned. With the use of Avatar Robots, an expert is able to quickly troubleshoot issues through telepresence. This removes the need for travel to the remote

site. Therefore, it reduces safety risks for the expert. Also, it is predicted to be more cost-effective and time-effective (less downtime) [4].

Furthermore, as stated in [4], "the current Covid-19 pandemic has resulted in increased health risks for care workers and numerous restrictions to social interaction among all citizens (e.g. social distancing)". In such a relevant situation, Avatar Robots can increase the safety of front-line workers and other professionals that have a lot of direct contact with other humans.

2.2.2 Telemedicine

In addition to the safety provided to front-line workers in medicine, other disciplines can also highly benefit from tele-robotics. There will always be a demand for highly educated specialist care. Especially in remote locations it can be difficult to respond to the demand. Avatar Robots may realise improve access to healthcare services and increase care quality while decreasing costs by reducing the need for healthcare professionals to travel [4]. The current state of the art is a less physically interactive approach: audio-video telemedicine. This form of telemedicine can help provide health-care services to areas with geographical barriers and/or limited resources [3]. It encompasses clinical teaching/mentoring, patient monitoring and consultative, diagnostic and therapeutic services [8]. Avatar Robots can be an addition to this existing technology. It can allow expert surgeons to provide guidance where the physically present surgeon often has limited experience with the treatment technique [9]. This is very important, because it can help patients in remote locations receive the care, they need without the surgeon being required to travel. This is supported by [10] who say that tele-robotics provides a promising solution to the problem of existing and rising demand for specialist care. Another advantage of using robotic medicine is the potential improvement precision in movement and its inherent resistance against fatigue and tremors. This can be very important in careful surgery such as cerebrovascular or cardiovascular operations, which can also be very lengthy.

Additionally, tele-robotics can provide large steps in the field of Minimal Invasive Surgery (MIS). This is a powerful technique that allows surgeons to do diagnoses without long recovery times, low assistance costs and the patient's integrity is protected [11]. Currently, the main techniques for diagnostic surgery are endoscopic or laparoscopic surgery. The first relies on high-quality video but lacks the ability to feel forces/torques and pressure they are exerting. The latter is based on stiff tools that the surgeon can manipulate directly. Therefore, they can keep a degree of "feeling". However, this technique lacks video

information. In contrast to these existing methods, tele-robotics can be a combination of these systems through sensor integration, force reflection, actuators and control. [11]

Furthermore, [10] goes on to argue that surgical robotics, coupled with AI capabilities such as machine-learning and outcome-based analyses may uncover new knowledge in surgery. This can be potentially ground-breaking. Machine learning can draw previously undiscovered pattern representations of data, and its response will only continue to improve as it gets fed more data. This can potentially make it easier to diagnose patients with more accuracy and certainty.

Lastly, the main limitations of research in the medical sector are legal and ethical and liability concerns [3]. For example, if the robot makes an error in its movement, it may cause harm to the patient. In this case, is the operator still responsible if he did not control that specific movement? There are a lot of unanswered questions and development should continue carefully and responsibly.

2.2.3 Classroom education

Tele-robotics may provide new possibilities for education. In particular, it can have an impact to improve equal accessibility to education [4]. This impact can be generated in twofold. Firstly, the quality of and access to education may improve since Avatar Robots allow teachers to not be restricted to teaching in the location where they live and work. Instead, teachers can operate any Avatar Robot and teach in any class that has access to such systems. The added benefit here is that there is little extra infrastructure needed, and it allows for more flexible teaching than a videoconference or recording does. For example, it enables interactive sessions, whiteboard drawing and walking around in the classroom settings. In this way, Avatar Robots can allow teachers to use remote education in a more natural way for both themselves and the students. Secondly, Avatar Robots can also be used by the students. Students can join classes from remote locations. This can bring high quality training to people who may otherwise not benefit from such education [4].

2.2.4 Remote visiting

The previous applications that have been stated all have a physical interaction that is required in the remote location. However, there is also a point to be made for the possibilities of the social aspects of Avatar Robots. For example, applications can be designed such as consultation appointments and social contact with friends and relatives. In this way, Avatar Robots could present as a more tangible alternative to video conferencing. This is supported by [4], who mention that Avatar Robots enable for a deeper level of social interaction than

video-conferencing by inclusion of critical social touch interaction, thus providing relief from the agony of social distancing and social isolation, for example in the current Covid-19 pandemic. Further exploring this avenue, an experiment has been done comparing trust in expertise between Avatar-, Video- and Robot-mediated interaction [12]. From their experiment it can be concluded that a virtual avatar that moves on a computer screen does not generate trust. However, if a robot does the exact same movements in a physical embodiment, responses of trust were much more positive. This is supported by [13] where it is implied that gestural cues help assess personality of the operator. From this, it can be concluded that physical presence certainly helps build trust of an operator, even if their identity is not shown. This is explained because the first has the strength of physical representation, and the latter has the advantage of carrying over the identity of the expert. From this, a costs and benefits analysis can be designed: Robot technology is very complex and costly, but does bring unique possibilities for remote physical interaction. Is it more important to have physical presence through a robot, or is a video interaction more suitable for a specific case? Another interesting thought is that this knowledge may imply [12] that a robot could increase the observer's level of trust when it has a more realistic appearance. If the physically present robot also looks more familiar and human, it is likely that this is more trustable. It is argued by [12] that in a next experiment a Geminoid system could be used. What this means is that robot-mediated interaction is potentially a viable alternative to video conferencing. The added benefits of physical presence may also present positive impact for regular social contact with friends and relatives, as compared to video chatting. For example, one could physically visit and (physically) interact with a distant relative without the time and resources needed for travelling there.

2.3 Ethical Concerns

As stated in the introduction of this research, it cannot be taken for granted that good intentions create only positive impact. Therefore, it is imperative to be aware of the ethical consequences and social risks attached to Avatar Robots. Moreover, mapping and addressing these consequences is deemed very important by [4]. However, this proposal [4] is also still working towards a responsible design reference document. This is a clear indication that more guidelines are still required. Therefore, in this section, ethical concerns are categorized and explained through three main topics: Safety and Reliability, Perceptual Dependency, and Control and Transparency. This knowledge is collected through an investigation on existing literature about Avatar Robots as well as adjacent technologies. These insights are used to

sketch the landscape from which a conclusion can be drawn on present threats and ethical concerns around Avatar Robots.

The primary goal for this section is to learn from is publications on Avatar Robots to collect and synthesize relevant ethical concerns. However, as with any other novel technology, only a few publications have been found on this specific niche technology. Also, Niemelä et al. imply in [14] that few studies have investigated the social concerns and impacts for mobile telepresence. For this reason, we need to broaden the scope of research, and investigate the adjacent technologies, Virtual Reality (VR), Augmented Reality (AR) and general Robotics. An ethical concern in another domain may imply the same concern in the domain of Avatar Robots.

2.3.1 Safety and Reliability

Two of the primary requirements of Avatar Robots are safety and reliability. The insufficiency of these two aspects leads to various ethical concerns. Telemedicine is a potent application of Avatar Robots, but there are some technical challenges to implementation. Surgeons in remote locations may receive assistance from surgeons in other geographical locations. This is especially helpful when the physically present surgeon has limited experience with a treatment technique [3]. However, there are still some concerns in the implementation of the technology.

Firstly, there is the importance of low-latency connection for control. As mentioned before, higher latency is associated with increased errors, which may cause harm to the patient. Furthermore, the question arises whether patients should be informed of the potential for such technical failures. What is also mentioned by [3], [15] is the risk for cyberattacks. Additionally, [3] mentions an example of a cyberattack on a hospital that has already occurred, which has raised serious concerns on the confidentiality and safety of telesurgery. Finally, if the reliability of the technology is not yet sufficient, patients and doctors need to be wary of these shortcomings. This raises concerns about consent, liability, and legal matters about using robots for remote surgery applications, which are the primary hurdles in implementation into surgery practices.

When one considers the broader scope of general Robotics, similar issues are mentioned. It is stated in [16] that the increasing variety of robots includes machines that can have negative effects such as bodily injury, invasion of privacy or reduced human contact. Furthermore, this risk of bodily harm is also mentioned in [3], and the risk of privacy breaches is reflected in the fear of cyberattacks in [3] and [15]. Although the concerns are

raised by [16] in a military context, it is realistic that these risks may also present themselves unwantedly in health care, public spaces, and home situations.

2.3.2 Perceptual dependency

The impact of VR technology on a user is instrumental in distinguishing ethical concerns of Avatar Robots. VR can be investigated to derive ethical concerns since its implementation is similar and adjacent to Avatar Robots. The operator of an Avatar Robot sees a representation of the real world on the remote location, but it is only limited to that: a representation. The sensory data can provide a realistic image and sound, but the operator is highly dependent on the interpretation the robot makes of the real, remote place. In this situation, bad intent can create convincingly realistic, but fake representations of a remote world. It is stated in [17] that both VR and Augmented Reality (AR) are highly persuasive. This is obviously the aim of the technology, but it can nevertheless be used for bad intentions. Furthermore, because of the immersion in a realistic virtual world, a sense of fantasy world may be created in VR. If a person exits this virtual world, their response to the real world may be less positive, as has been discovered from psychological therapy that employs VR [17]. An interesting example for such a situation in Avatar Robots is proposed by [4]. In this example, an individual is in a wheelchair. However, through Avatar Robots this person can go anywhere and do anything. While this may be a wonderful experience, it can also lead to disappointment in this individuals real life. In comparison their real life now feels less exciting. This may result in a pity for oneself in the real world, where they only want to be in the virtual world. Whether this is ethically sound is to be discussed.

As a result, the theories of dependency of the fantasy world in VR can also be extended to Avatar Robots. This, however, can also be used in a bad way through misleading the users, as illustrated by [4]. Rather than playing a violent war game on a living room console, people could remotely log in to Avatar Robots and battle in remote places. Due to the persuasive nature of VR, they might not even know that they are not playing a traditional game on a console. Furthermore, also [17] states the importance of legal and ethical responsibilities for actions carried out by a robot that is being remote controlled by an interface (Avatar Robots). The harm may not be caused purposely, as the operator can argue that his actions were not realized through the interface the way he intended. In this case, [17] wonders under which jurisdiction this should fall – that of the operator, the robot or the robot's manufacturer? In other words, would the gamers be responsible for harming civilians if they thought they were just playing a fantasy game? This is a similar case to what is

mentioned in [3] and [15], but the difference is that in [17] it is about intent, rather than technological stability. However, the outcome of undesirable actions – without bad intentions – is the same.

2.3.3 Control and Transparency

It is important to make clear agreements about who is in control and who is permitted to do what. For example, a local government authority or company may want to change, add or remove functionality of the Avatar system. If this happens, the product deviates from the original design. Clear agreements need to be made to conclude on what is allowed. Furthermore, it is important to be transparent about this towards the stakeholders. This is in coherence with the value of Wijze Transparantie that is proposed in [18]. There are serious concerns found in the discussion of control and permission, and the transparency of the decisions made on this. As mentioned before, VR and AR systems boast immersive and persuasive aspects, and therefore a speculation of malicious implementations is mentioned. In addition to this, [19] asserts the importance of regulating who should be permitted to make these augmented realities. This augmentation has two dimensions. Firstly, there is the augmented representation of the space, being a public or private area. Being aware of the impact that can be caused by a realistic, but misleading environment, [20] raises the question of whether someone should be allowed to take ownership of what a visitor sees of a public space through AR. In this case, the owner can control what you see, much like on web sites. This is interesting because research can learn from web sites about how this might unfold. The amount of advertising on websites can sometimes overwhelm the experience of the actual content on the website. What would the world look like if people could serve advertisements everywhere? A point could be made that the entire world would look like Times Square. Secondly, there is the augmented representation of the (real) people in the area. In VR, a virtual representation of a real person should also be included in the golden rule of reciprocity (principal of treating others as one desires to be treated themselves). This is proposed by [17], and it is relevant because people may have had bad experiences in a virtual environment with a virtual representation of a person, or a specific group of people. And, although this might only be in a VR environment, a person may extend this perspective and generalize his opinion to the real world. It is argued by [17] that this may also happen with representations of individual people that the participant knows. The immersive experience of VR can be so persuasive that it can change a person's perspective on a place, a person, or a group of people in the real world. In the end, it is imperative that businesses,

system integrators and other people in a position of control are transparent about their decision-making strategies about software, design and data collection. As mentioned before, this movement towards transparency is an important step in responsible design, according to [18].

2.4 Direct impact on SDG's

In order to gain insight on the impact on the SDG's of Avatar Robots, one concrete option is to consider the direct effects of the applications of Avatar Robots as they are stated in Section 2.2, as well as the effects of the concerns that are stated in Section 2.3. The approach for this insight has been to highlight the most obvious direct impact that can be realised per application. Furthermore, the negative impact that is outlined by the concerns is also found through a negative effect on some specific (sub) SDG's. The definition for a direct impact is the primary resulting effect of an action. Identifiable ripple effects are considered indirect impact and are not considered at this stage. The list of SDG's that have been highlighted and are referred to can be found in Appendix 7.1.

We have selected and processed the SDG's based on insights from Sections 2.1, 2.2 and 2.3 and an analysis of the description of the sub-SDG's. For this reason, this selection is not a conclusive overview, but rather a starting point for thinking about impact and risks based on a technology-driven analysis.

2.4.1 Applications

Firstly, the direct effects of telemedicine are likely to be strongest on SDG 3: *Ensure healthy lives and promote well-being for all at all ages*. In developing countries, it is found difficult to educate people to become doctors domestically, and especially to retain these people in their country of origin. As a result, the influx of new doctors in developing countries is unoptimized at best. This becomes evident if one investigates the amount of physicians per 1000 people in a country [21], as seen in Table 1. It should be noted that there are multiple factors at play for this result, many of which exceed the scope of this research. However, we can say with certainty that there is a significant improvement possible in the number of physicians in developing countries. As part of a solution, telemedicine brings the possibility for expert care to reach developing countries and areas with geographical barriers without the necessity for relocation (permanent or temporary) of the physician. This may reduce the mortality rate in developing countries, where specific knowledge may be insufficient. Additionally, local physicians and nurses may learn by example and mentoring through telemedicine, which strengthens the capacity of the health workforce in developing

countries. This addresses sub-SDG's 3.c, which addresses the "*substantial increase in health financing and the recruitment, development, training and retention of the health workforce in developing countries, especially in least developed countries and small island developing States*" and sub-SDG 3.d, which states to "*strengthen the capacity of all countries, in particular developing countries, for early warning, risk reduction and management of national and global health risks*".

Country/region	Physicians (/1000 people)
Netherlands	3.605
India	0.778
Sub-Saharan Africa	0.234

TABLE 1 - PHYSICIANS PER 1000 PEOPLE [21]

Secondly, the example of mentoring can also extend into the application of classroom education. It is stated in [22] that robotics may be used to enrich and expand the educational environment of young children. In the perspective of [22], it is the child that is remotely present in a class (From Japan to US in their case). Additionally, remote education can work the other way around, as it may also be converted into remote presence for the teacher. If this avenue is pursued, this can be another example where knowledge can be spread more easily. It has been discovered that there is an education gap between rural areas and cities [23], and this effect may be even stronger in countries where inequality is higher. If a teacher from the same country can be found, any language and culture barriers in remote education may be well diminished. This makes tele-robotics a viable part of a solution to the inequality in education without necessitating relocation (permanent or temporary). Based on these possibilities, it can be concluded that the most applicable SDG will be SDG 4: *Ensure inclusive and equitable quality education and promote lifelong learning opportunities for all.* Specifically, this may have a strong impact on those who might not have had access to education, for example in rural areas. In this case, sub-SDG 4.5, which addresses to "*eliminate gender disparities in education and ensure equal access to all levels of education and vocational training for the vulnerable, including persons with disabilities, indigenous peoples and children in vulnerable situations*" may be affected relatively stronger. Furthermore, in close relation to this is education about climate awareness. Therefore, through education there may also be a direct impact on sub-SDG 13.3: *Improve education, awareness-raising and human and*

institutional capacity on climate change mitigation, adaptation, impact reduction and early warning.

Thirdly, Avatar Robots can have an impact on sub-SDG 8.8: *Protect labour rights and promote safe and secure working environments for all workers, including migrant workers, in particular women migrants, and those in precarious employment*. Improvement on this goal is addressed by taking people out of dangerous situations for their work. Over the last decades, the average workplace has changed vastly for the better, and generally work environments are safer. Next to that, a lot of labour has been automated, taking people out of unfavourable working environments. However, there are still examples where critical human evaluation and operation cannot (yet) be automated. An example of this is the voltage switching equipment in industrial installations, as explained in Section 2.2.1. Using Avatar Robots, workers should not need to sacrifice on human capabilities whilst still taking people away from dangerous situations. Furthermore, experienced mechanics could use their expertise to control these robots without putting themselves in danger. This may also extend to firefighters and first responders in unknown and/or dangerous locations. In these situations, Avatar Robots may enable a safer way of providing local care in emergency situations without putting the responders in danger.

Lastly, remote visiting through Avatar Robots can have a direct impact on sub-SDG 5.4: *Recognize and value unpaid care and domestic work through the provision of public services, infrastructure and social protection policies and the promotion of shared responsibility within the household and the family as nationally appropriate.* In areas where the healthcare and provisional infrastructure are not as well developed, more responsibility is put on households and families. Additionally, it is often women that spend most time doing unpaid domestic care work [24]. The traditional household's dependency on women refrains these women to enter and stay in the labour force. Avatar Robot systems can provide effective infrastructure for other (remote) family members to help out at home [4], as well as allow the person at home to be more efficient with their time using the capabilities of an Avatar Robot. For example, an Avatar Robot does not get tired, it can carry more weight and is more dextrous than a human. Furthermore, as explained in Section 2.2.4, remote consultation can potentially benefit from the use of Avatar Robots. The main advantage to use Avatar Robots in remote consultation is in the acknowledgement of the importance of physical presence. If, through Avatar Robots, more individuals could receive reproduction and family-management education this would specifically impact the latter part of sub-SDG 5.4 through breaking with gender norms and promoting shared responsibility.

2.4.2 Concerns

In parallel to the direct positive impact that can be found by looking at the applications, the investigated concerns surrounding Avatar Robots can have a negative impact on the SDG's if these are not taken into account.

Firstly, impact on SDG 3 may be diminished or even negatively impacted when Avatar Robots are implemented when they behave faulty or inconsistently. Acceptation of new technology is a critical process. Thus, technological stability is a necessity for Avatar Robots to be implemented. If this is not the case, no positive impact on SDG 3 can be made with Avatar Robots. Moreover, the impact becomes negative when systems are implemented when they are not well-developed enough. If the technology is not up to par, or not reliable enough, critical surgery may not be successful due to interruptions in connection.

Secondly, sub-SDG 9.b – "*Support domestic technology development, research and innovation in developing countries, including by ensuring a conducive policy environment for, inter alia, industrial diversification and value addition to commodities*" – may be negatively impacted based on the concerns around control as presented in Section 2.3.3. In general, domestic development may be staggered by the rollout of innovative technology from more well-developed regions, as it rules out the local competition through competitive advantages such as resources and knowledge. This effect may be reduced if the control aspect of the technology is more open source. If this is possible, domestic industries can join the process of innovation by building on the existing technology and develop a more locally suitable adaptation of the immigrated technology. This is closely connected to the latter part of sub-SDG 4.7: … *Appreciation of cultural diversity and of culture's contribution to sustainable* development. The context of SDG 4 is in education. Since education and mentoring have been identified as promising applications for Avatar Robots, not taking these concerns into account may cause a negative impact or a less positive result. The problem lies in policy management for Avatar Robots. Currently, primary developments of Avatar Robots happen in Western or developed Asian cultures. Something to look out for in implementing Avatar Robots is the value of culture and the related expectations that lay the groundwork for intuitive interaction with a robot, both for the operator and for the recipient. In the case of current developments, that means that Avatar systems need to be a framework on which domestic development institutes can build. This allows for diverse applications and designs that suit different needs and desires of end-users based on cultural and societal differences. If this does not occur, a Western perspective may be imposed on the technology, which might not have the same success in different cultures. Therefore, it needs to be considered who is

in control, and developers should be transparent about the context and background of certain decisions that are made. This can be used to reflect on the accuracy of representing specific cultural needs, and it may highlight where adjustments of reasoning and implementation can be made to suit specific cultures better.

Closely related to this is the concern for the perceptual dependency of Avatar Robots. In Section 2.3.2 this has been explained on the basis of VR systems. The impact these systems can have on an operator may be lasting and can translate to behaviour in the real world. Using Avatar Robots, it will be possible to virtually 'cross borders'. In this situation, it will be vital to adhere to and respect country policies and leadership. This is described in sub-SDG 17.15. Avatar Robots should not be a system that can be used to violate local laws based on the fact that the operator is not operating from the country concerned. Therefore, not only on a cultural level, but also on a political level, Avatar systems should be flexible enough to be applicable in multiple locations. Also, operators should be aware of local customs and adhere to them.

Lastly, loosely but sufficiently connected to the general theme of the proposed concerns is the demand for *multi-stakeholder partnerships that mobilize and share knowledge, expertise, technology and financial resources, to support the achievement of the SDG's in all countries, in particular developing countries,* (sub-SDG 17.16). Expressed differently this means that multiple perspectives are included to take different values and views into account in the development of a complete system that may be adapted to suit the maximum number of users. This extends the multidisciplinary practice within a country and stresses the importance of a multi-faceted global collaboration on Avatar Robots and their requirements and their goals.

2.5 Conclusion

In this chapter, we have discussed the possibilities and concerns around Avatar Robots based on literature examples. Furthermore, an analysis of the direct impact on short- to mid-term is presented.

However, this analysis only investigates four specific applications. As a result, it is relatively near-sighted and only a small subset of the SDG's seems affected. Furthermore, it does not take into account any ripple effects on the SDG's. As can be found in the research done by [25], there are substantial ripple effects where impact on a specific SDG may be a catalyst for impact on a set of other SDG's. For example, improvements made on inclusivity

(of women) and in sustainability (through right to repair[1]) may positively benefit many other (sub-)SDG's. Therefore, the overall impact may extend further than the SDG's that are highlighted in this chapter. In order to gain a more detailed overview of the overall impact of Avatar Robots, the indirect impact of Avatar Robots on the SDG's should also be investigated.

Therefore, we discuss the indirect impact of Avatar Robots in the next chapters. The goal is to explore how Avatar Robots may be a vehicle for broader impact on the SDG's as an integral system. It is important to discover these long-term goals for broad impact at an early stage of development, as this ensures that development can take specific design requirements for the long-term into account.

[1] The right to repair electronics refers to government legislation that is intended to allow consumers the ability to repair and modify their own consumer electronic devices, where otherwise the manufacturer of such devices requires the consumer to use only their offered services. Source: https://en.wikipedia.org/wiki/Electronics_right_to_repair

3 METHODOLOGY

In this section, the methods for researching the indirect impact of Avatar Robots are proposed. An analysis of the ripple effects of sub-SDG's is made, based on the systemic overview of the SDG's as researched by Weitz et al. in [25]. Based on this, a selection is made of the SDG's that are overall the most impactful. This set of sub-SDG's is used as a basis for a brainstorm session to explore the potential impact of Avatar Robots on these SDG's. Based on the outcomes, we work towards design guidelines for Avatar Robots to maximise indirect impact in the long term.

It should be noted that the findings by [25] are not all-inclusive or meant as a method for scientific assessment. Rather, it is intended to be used as a tool that supports policy making, with a high degree of transparency and opportunity for engagement. It is intended to help kickstart a way of working with the SDG's as an interactive system. Furthermore, it should be noted that this research is based on the context of Sweden in 2018. The analysis and final outcomes are subject to deficiencies in the scoring approach (where the SDG's have been given a rating based on their positive or negative impact). This scoring process is judgement-based and has been done with limited in-house resources. Therefore, this analysis may not coincide with an accurate representation of other societies or locations around the world. With acknowledgement of the value of Wijze Transparantie in [18], it is imperative to highlight the context of this reference. However, it does present a fruitful foundation to work with for the purpose of identifying the most catalytic sub-SDG's.

3.1 SDG's as a system

In order to investigate the indirect impact of Avatar Robots, it is important to treat the SDG's as a system of goals that interact with each other. As stated in Section 2.5, there are substantial ripple effects identified between the SDG's. With the intention to create the maximum positive impact in the long term, Avatar Robot development can benefit from such ripple effects analyses. More research needs to be done on how to work for the SDG's as a system, but an interesting start is to look at the most catalytic sub-SDG's and focus to create a positive impact on these. This research makes a start in developing Avatar Robots as a vehicle[2] for positive impact on the SDG's, by recognizing the ripple effects in the SDG's and aiming for the most attractive SDG's in that regard.

3.2 Sub-SDG's as catalysts

It is a problem that the Sustainable Development Goals (SDG's) are frequently used as individual goals. The result of this is fragmented impact that does not take into account the fact that an action may be a catalyst for progress in other goals, both positive and negative. In reality, the set of goals acts and should be treated as an interconnected system. Some sub-SDG's tend to have a more positive influence on other SDG's through ripple effects, these are regarded as catalytic. As stated in Section 3.1, it is interesting to aim for a positive influence on these sub-SDG's.

3.3 Selecting sub-SDG's for maximum impact

In order to gain an insight in the ripple effects, the network analysis executed by [25] is referred to as the foundation. In this paper, a cross-impact matrix and a network perspective are presented to show the systemic effects of the SDG's. In other words, it provides insight in the ripple effects that SDG's may have on each other.

For this analysis, the choice has been made to refer to the network analysis over the cross-impact matrix that is proposed by [25] since it simplifies analysis and visualization. Furthermore, the results of the full network analysis have been synthesized into a network of only the most positive interactions, based on a +3 ranking of influence. This synthesized network visualisation will be used to distinguish the set of sub-SDG's that have the most beneficial effect. This network can be seen in Figure 1.

[2] In this case, the term 'vehicle' is expressed metaphorically, similar to a Trojan Horse: Avatar Robots serve as a carrier for broad change.

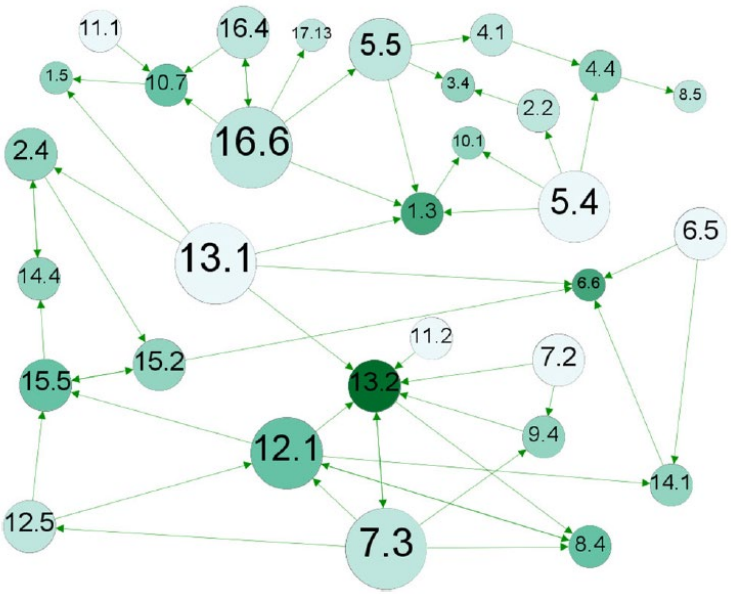

FIGURE 1 - NETWORK ANALYSIS OF MOST CATALYTIC SUB-SDG'S [25]

Note that the direction of the arrows visualises the direction of the impact. In this chart, a darker node relates to this sub-SDG being more influenced by other sub-SDG's. The size of the nodes is an indication for the amount of direct influence that a particular node has on other nodes.

The goals 7.3 (energy efficiency), 13.1 (climate change adaptation) and 16.6 (effective institutions) have the largest nodes, and therefore the largest positive influence on other goals. Additionally, goals 5.5 (women's participation) and 5.4 (unpaid/domestic work) also exert a strong positive influence, as well as goal 12.1 (sustainable consumption/production). Furthermore, it is interesting to note that target 13.2 (climate change policy/planning) is the most positively influenced goal in this analysis. It distinguishes itself with a darker colour. Additionally, it is being positively affected by three lines which have already been identified to have a great positive influence. This shows that the most influencing goals do have a tendency to bring improved progress towards goal 13.2. Also, it is interesting to note that goals 13.1 (climate change adaptation) and 5.4 (unpaid/domestic work) have a large positive influence but are not positively influenced by any other goal. Since these goals do not profit from ripple effects, progress on these SDG's requires a direct approach. Therefore, it is beneficial to include these goals in the brainstorm session, since these goals are then directly addressed.

3.3.1 Chosen SDG's

For the brainstorm, the decision has been made to work with a set of 5 SDG's. The selection is made from the previously analysed list of most influential goals. However, specifically goal 16.6 has been left out of this selection in spite of its influence on other goals. A discussion on goal 16.6 is expected to quickly lead into an analysis of organisational structures and their requirements, rather than requirements for the Avatar Robots themselves. Following the analysis in Figure 1, the most catalysing SDG's are picked for the brainstorm session. This accounts for systemic ripple effects and results in an interesting mix of SDG's from different domain. The following five sub-SDG's are chosen for the brainstorm session:

7.3: Energy Efficiency

By 2030, double the global rate of improvement in energy efficiency

13.1: Climate Change Adaptation

Strengthen resilience and adaptive capacity to climate-related hazards and natural disasters in all countries

12.1: Sustainable Consumption/Production

Implement the 10-Year Framework of Programmes on Sustainable Consumption and Production Patterns, all countries taking action, with developed countries taking the lead, taking into account the development and capabilities of developing countries

5.4: Unpaid/Domestic Work

Recognize and value unpaid care and domestic work through the provision of public services, infrastructure and social protection policies and the promotion of shared responsibility within the household and the family as nationally appropriate

5.5: Women's Participation

Ensure women's full and effective participation and equal opportunities for leadership at all levels of decision-making in political, economic and public life

3.4 Brainstorm session design

The goal of this brainstorm session is to spark a process of thinking for maximum impact in the future. This corresponds with the theories in [18], where it is stated that the most beneficial developments are developed for "here and now as well as elsewhere and later". According to [18], it is important to implement a broad perspective into development. Additionally, design guidelines for the present should take desires and requirements of the future into account. It is less sustainable to change production to make it more sustainable, than it is to implement sustainable production from the start.

The approach for the brainstorm is to imagine scenarios that are aimed at reaching one of the five catalytic sub-SDG's as identified in Section 3.3.1. In this first phase, the participants are provided a brief introduction of one of the five sub-SDG's. Then, the participants are tasked to create scenarios that may be used to reach this SDG. For this phase, the participants are given approximately 5-8 minutes, based on the diminishing amount of new input.

The second phase of the brainstorm is aimed at distilling these scenarios into the requirements of Avatar Robots. These requirements can be seen as guidelines for development of Avatar Robots, to create impact on the sub-SDG that is discussed. These two phases will be iterated for all five of the selected sub-SDG's.

3.4.1 Background information of sub-SDG's

It is important to reach a common understanding between participants of what the selected sub-SDG's mean, and how this may translate into action that can be taken for progress. Since participants are potentially only vaguely familiar with the SDG's, let alone the specific sub-SDG's that are chosen, some background research of these sub-SDG's is provided in the brainstorm session.

Firstly, Energy Efficiency (SDG 7.3) is defined as using less energy to perform the same task [26]. Additionally, improving energy efficiency is often seen as the cheapest way to reduce the use of fossil fuels. Based on this information, these guiding questions are introduced: "How can Avatar Robots (help) make buildings, powerplants, vehicles and freight more efficient?", "How can Avatar Robots help people to be more efficient?", "How can Avatar Robots function more efficiently?" and "How can we learn from nature's efficiency?". The last question is inspired by [18], where developers are stimulated to learn from evolutionary efficiency that is seen in nature. A relevant anecdote to illustrate this is about bumblebees: The bumblebee is too heavy to fly based on simple aerodynamics given the

bumblebee's weight and wing size. However, special movements create air vortexes underneath the wings. These vortexes add the required lift for the bumblebee to fly.

Secondly, Climate Change Adaptation (SDG 13.1) represents the implementing action to respond to the impacts of climate change as well as prepare for future impacts [27]. Furthermore, it is also stated in [27] that the adaptation action should follow a country-driven, gender-responsive, participatory and fully transparent approach that considers vulnerable groups, communities and ecosystems. It should be based on science and traditional knowledge, knowledge of indigenous peoples and knowledge systems. In other words, adaptation should be specific to a location and problem situation as well as inclusive and transparent. Furthermore, approaches should align with local norms, and accept local knowledge systems. This remark for inclusivity, transparency and to adjust for local situations is noteworthy, and a clear example of how a broader perspective should be implemented. This is similar to what is presented in [18]. With this information, these questions are provided as guidelines: "How can Avatar Robots be used to improve adaptation/resilience regarding climate change?" and "How can Avatar Robots help with the global scale of this issue?". The latter guiding question is included specifically to draw out scenarios that benefit from the flexible nature of Avatar Robots: The concept allows the core system to be extended and modified to fit specific purposes.

Thirdly, Sustainable Consumption/Production (SDG 12.1) is about doing more and better with less. It is also about decoupling economic growth from environmental degradation, increasing resource efficiency and promoting sustainable lifestyles [28]. Additionally, this sub-SDG lends itself very well to brainstorm about ways the production and consumption of Avatar Robots can be made more sustainable. If this is taken into account, the impact of Avatar Robots is enlarged, and the technology can be used as an example. This further increases the capacity of Avatar Robots to function as a vehicle for positive impact. Based on this background information, these guiding questions are proposed: "How can Avatar Robots reduce product waste or increase efficiency in other systems? (Food, electronics, production materials)" and "How can Avatar Robots be designed sustainably?"

Fourthly, Unpaid/Domestic work (SDG 5.4) is about recognizing and valuing this work. Also, it concerns promoting shared responsibility within the household and the family. This sub-SDG strives to even out the imbalance between men and women. It is argued by [24] that, on global average, women spend 2 to 10 times more time on unpaid care work than men. Consequently, a lower labour force participation for women is kept in place. In turn,

this stagnates progress on the reduction of a gender gap. However, it has been shown that a reduction in time spent on unpaid care work leads to an increase in female labour participation [24]. Therefore, widespread positive change may be possible if Avatar Robots can be implemented to help decrease the amount of time spent in unpaid care work. This background information has led to these guiding questions: “How can Avatar Robots play a role in time-saving technology and infrastructure? Existing examples are electrification and improving access to water.” And “How can Avatar Robots help tackle gender norms and stereotypes? This is a first step towards shared responsibility for care and housework.”

Lastly, Women’s Participation (SDG 5.5) is closely connected to the previously mentioned SDG 5.4. However, in sub-SDG 5.5 the topic is extended to include all aspects of life, rather than a specific focus on domestic work. This sub-SDG strives to ensure women’s full and effective participation and equal opportunities for leadership at all levels. Technology can be very effective for women empowerment. For example, it is stated in [29] that technology can be an effective organizing tool to progress towards peace. It can enable women and girls to participate in democracy, civic action and peacebuilding. However, relatively fewer (26% less) women tend to have smartphones compared to men. Coincidingly, digital skills and (digital) literacy are also lower. Building on this knowledge, these guiding questions are included: “How can Avatar Robots empower (working) mothers?”, “How can Avatar Robots improve women’s digital literacy?”, “How can Avatar Robots help women protect themselves?”, “How can Avatar Robots promote human dignity and gender equality?” and “How can Avatar Robots protect and promote diversity and inclusiveness?”

It is noteworthy that this specific sub-SDG has relatively more guiding questions than the other sub-SDG’s that are included in the brainstorm session. This has been done purposely because this topic is deemed very difficult to brainstorm about. Given the fact that the researcher has little knowledge nor experience regarding this topic, it is expected that the participants do not either. Ideally, this research would have included a participant that is experienced and/or knowledgeable in this field. However, given the short timeframe of this research, that could not be achieved. In order to compensate for this, the necessity for background information behind the SDG and its applications has been introduced. The sections of background information have been included stemming from a lack of knowledge of this sub-SDG. It is imperative to work with a wide perspective and account for different groups. It is acknowledged that this measure is not all-inclusive, but it is a step in the direction of full awareness and inclusivity.

Furthermore, it is acknowledged that there is a potential overlap in responses between Energy Efficiency (SDG 7.3) and Sustainable Consumption/Production (SDG 12.1) as well as Unpaid/Domestic work (SDG 5.4) and Women's participation (SDG 5.5). For this reason, the order of rounds in the brainstorm session has purposely spread these out over the session to avoid repetition in quick succession. This is done with the intention to stimulate new and original input in the later rounds.

3.4.2 Brainstorm session realisation

The brainstorm sessions are designed to take place entirely online, using a digital workplace (Miro) and a video conferencing tool (Google Meet). The choice for a digital session over a physical session is made to avoid dependency on Coronavirus regulations. In this way, participants and researchers can be certain the meeting need not be cancelled due to changing measures. It is important to adhere to the measures as set by the Dutch government, and this research should pose no exception to the applied measures.

The platform of choice for online collaboration is Miro. Miro is an online interaction platform that allows a custom design of the workspace. Participants can create virtual post-it notes and drag these to sections of "whiteboards". This, in conjunction with a videoconference using Google Meet allows effective communication and collaboration. In a way, it is a close simulation of a real brainstorm session. It is desirable to use a similar approach to a physical brainstorm session due to the creativity that it sparks by allowing all participants to participate simultaneously.

In this digital workspace, a virtual whiteboard space has been designed for every sub-SDG. These workspaces provide the background information that is explained in Section 3.4.1 on the side, and the virtual whiteboard is designed to be filled in from left to right. Participants can grab a post-it note and write their input on it. The post-it note can be dragged to the destination. What's beneficial about Miro is that participants can see each other's input and mouse movements in real-time. This further strengthens the collaborative experience, in spite of being online. An excerpt of one of the brainstorm sessions can be seen in Figure 2. The Google Meet videoconference is only used for communication during the brainstorm session.

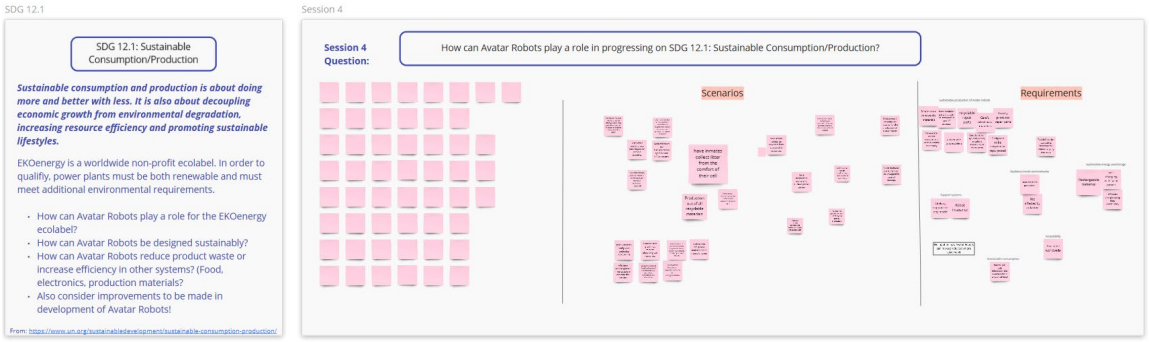

FIGURE 2 - BRAINSTORM WORKSPACE IN MIRO

3.5 Processing of results

The results of the brainstorm session are categorized and labelled by similarity and processed into diagrams. These diagrams are horizontally distributed from abstract to concrete (left to right). This means that the starting point in the diagram is the sub-SDG, and the endpoints are requirements that follow from the SDG's. This creates a visualisation of the breadth and depth of the input. These diagrams include the direct impact analysis from Section 2.4 as well, to allow for comparative analysis in the Discussion (Chapter 5).

4 RESULTS

In this section, the results from the brainstorm session are synthesized. The goal of the synthesis is to provide an overview of design guidelines for Avatar Robots to maximise positive impact. This is done by aiming for future progress on or achievement of catalytic sub-SDG's. The results are not ordered by importance. The full brainstorm session workspace is included in Appendix 7.2.

4.1 Time efficiency

The most prevalent advantage of Avatar Robots is that it reduces the need for travel. Therefore, Avatar Robots are an attractive approach to reduce time and energy spent on travel. The need for travel is very broad and commonplace, and it is for that reason that there are scenarios tied to every provided sub-SDG that stem from reduced travel time/resources. More specifically, for sub-SDG 7.3 (Energy Efficiency) the scenarios are very sober, and similar to the teleoperation applications that are illustrated in Section 2.2. Scenarios include remote teaching, remote physical conferencing and remote consultation with the added benefits of time and resource efficiency as well as removing humans from dangerous situations.

Also, time efficiency has proven to be applicable for scenarios that target sub-SDG's 5.4 (Unpaid/Domestic work) and 5.5 (Women's participation). As identified in Section 3.4.1, a decrease in time spent doing unpaid/domestic work tends to increase women's participation in the labour force. The scenarios that fulfil this progress are travel-reducing methods that allow the paid-working parent to help out remotely as well as allowing the domestic care work to be done more time-efficiently. Additionally, it allows more flexibility and opportunities in part-time working as work commuting is eliminated. This may provide more options for people to acquire and maintain a paid job besides their unpaid care work. Given that this is likely to benefit women stronger than men, this is a step towards women's participation and empowerment. Furthermore, the reduction of time spent travelling allows for informal care to be shared among a larger group of people. This means that a bigger part of the family can take care of those in need. Frequently this burden rests on the shoulder of the relative that lives closest-by.

In order to achieve time efficiency, an Avatar Robot is argued to require to be operational in very remote, potentially rough areas. This requirement is found in the sessions

on sub-SDG's 7.3, 5.5, 12.1 and 13.1. Furthermore, in all sessions, accessibility of Avatar Robots is pleaded for, so they can be put to use directly. This minimises the time spent travelling, even if it is only the robot that displaces. Furthermore, especially important for achieving sub-SDG's 5.4 and 5.5, Avatars must have sufficient fine motoric skills to match human interaction with objects and other persons. Additionally, more creative requirements are proposed. Automation of tasks was coined as an improvement for time efficiency in repetitive household chores. The concept behind this is that the Avatar Robot recognizes a specific task and learns from your behaviour. Therefore, over time it would learn to do it by itself. This is proposed to have an impact on reducing domestic work (sub-SDG 5.4). Furthermore, Augmented Reality (AR) could enhance the observer's experience of the remote location. Based on image recognition, the system could help identify objects and provide useful information to the operator. This extra layer of information can allow the operator to behave more time-efficiently. This idea stems from sustainable consumption (sub- SDG 12.1) of an Avatar Robot's resources.

4.2 Resource efficiency

Besides a reduction in time spent, a significant advantage of Avatar Robots is the possibility for increased resources efficiency such as materials and energy. The most prevalent benefit is the reduction of fuel consumption that is otherwise required for travel, this is effective towards SDG's 12.1 and 7.3. For example, in a scenario where an Avatar Robot can fulfil any remote tasks, humans can live anywhere on the world as they are no longer dependent on their work. Additionally, the added benefit that is introduced is that the spreading of citizens can spread pollution over the world, rather than concentrate pollution in cities. This same benefit also returns in the rounds of SDG 13.1 (Climate Change Adaptation) and SDG 12.1 (Sustainable Consumption/Production). Furthermore, if more jobs can be done using Avatar Robots, the world can gradually transition into a more streamlined source of energy. Instead of using a range of combustion fuels and electricity, energy supply can transition towards electricity only. This is more efficient due to the reduced variety of resources and simplification of transport, as less different (and non-renewable) resources are used. Additionally, if humans can live closer to the resources, it is imaginable that the amount of oil transport can be reduced. This benefits the energy efficiency (7.3) but has a positive impact on the climate change adaptation (12.1) as well: the reduction of oil transport may reduce the chance for an environmental disaster if a carrier crashes. Furthermore, since the operator of an avatar robot can live anywhere, climate change adaptation may take on a new

avenue. Theoretically, Avatar Robots reduce/remove the need to go outside. This enables humans to live in otherwise uninhabitable areas, including under water, whilst contributing to society.

Moreover, the resource efficiency extends beyond energy required for travel. In the brainstorm session it has become clear that there are interesting measures to be taken to make Avatar Robots more energy efficient as a technology. These requirements were most common in the session on energy efficiency (7.3), but there is a substantial overlap found in the session on sustainable consumption (12.1). Firstly, Avatar Robots have to be powered by renewable energy sources, and the industry to produce Avatar Robots should be energy efficient too. This can be achieved by using renewable energy and their own residual energy for power. Furthermore, it was proposed that Avatar Robots should have energy recovery systems. Examples of this are energy harvesting and regenerative braking technology. This will allow an Avatar Robot to be more energy efficient. Lastly, more creative benefits regarding energy efficiency are introduced. For example, the use of Avatar Robots may reduce the substantial need for heating and air conditioning in buildings. These systems use high amounts of energy and are potentially less intensively used. Lastly, commutes can be more efficient as Avatar Robots can distribute more densely in transport services. In other words, more robots than humans can be put into a bus or a train. In this case, Avatar Robots do not only reduce the necessity for travel, but also make the commute more efficient.

Resource efficiency can also benefit from a responsible selection of materials that are used. Material efficiency is most prevalently explored in the sessions on energy efficiency (7.3) as well as sustainable production for sub-SDG 12.1. Efficient use of materials can be achieved by limiting the selection of production materials to low-energy, recyclable, and modular components. The modular aspect is inspired from the concept of the Fairphone in the session on sustainable consumption and production (12.1): a modular mobile phone which is designed to last and be effective over a long period, as it can be repaired with user-replaceable components. If modules can be serviced and/or replaced by the operator, the Avatar Robot is less likely to be disposed of. It is proposed that this can be substantiated through lifelong support systems or insurance policies that make repair accessible to the end users.

4.3 Safety

As has also been discovered in Section 2.2.1, Avatar Robots can provide promising opportunities to keep humans away from physical danger. In the brainstorm sessions, this has led to direct applications for Avatar Robots as well as more creative, heroic visions for Avatar Robots to save lives in environmental disasters.

Firstly, Avatar Robots can reduce physical strain on human bodies caused by heavy lifting. A few direct applications were introduced as benefits to the solutions for energy efficiency (7.3). Avatar Robots can be used as a substitute for physical work, as they can be used to do heavy lifting. The added benefit, in contrast to using a forklift, is that human dexterity is not compromised in the operation. Furthermore, hard to reach and dangerous areas – for example, around nuclear power plants or geysers – can be supplied safely without endangering humans. This directly reduces the risk of accidents and may save lives.

Secondly, more heroic visions for improved safety using Avatar Robots were created in the session on climate change adaptation (13.1). In order to save human lives in environmental disasters, Avatar Robots can be implemented to reduce the need for first responders to go outside in hazardous situations. It allows quick on-site presence, even in remote areas. Specialists can also go to more remote locations quicker. Furthermore, different Avatar Robot implementations may require specialised design to respond to different disasters. For example, a fireproof avatar could be on standby near areas that are prone to fire. Additionally, another system may be waterproof and/or be used to quickly build a dam to combat flooding. As a result, it is proposed that Avatar Robots can be tailored to handle in specific natural disasters, either to combat the disaster or to evacuate locals to safety. To achieve this, the requirements are also specific to the given situation. But, generally accepted is that the systems need to be durable and resistant to wear. Additionally, similar to what is stated in Section 4.2, repairability is a requirement in these scenarios as well. In general, in order to provide safety, Avatars need to be durable as well as repairable. Additionally, repair or replacement should not be a big issue: repair should be as time-, resource- and cost-efficient as possible.

4.4 Women's emancipation and gender norms

The sessions on women's participation (5.5) and unpaid/domestic work (5.4) had a lot of overlap, since both sessions sparked innovation for Avatar Robots to catalyse emancipation and combat gender norms.

Firstly, Avatar Robots can allow for more flexible work patterns as they reduce travel. Potentially, this can make it easier for mothers to join and/or stay in the labour force. Also, in the labour force the gap between the physical strength of men and women can be bridged by executing a physical task with Avatar Robots.

In addition to allowing women to contribute more to the labour force, Avatar Robots can also be used as a vehicle for women empowerment. For example, in the session on women's participation it became evident that direct empowerment of women is an important scenario. Empowerment can be created through applications of Avatar Robots such as networking (Women Mediator Networks[3]) and interaction with role models, (anonymous) activism as well as safe travel at night, as it is the robot that travels. In order to achieve this, the Avatar needs to be accessible in every community, and easy to use for everyone.

In order to empower women, it is stated in [29] that technology can be an effective organising tool towards peace: It can enable women and girls to participate in democracy, civic action and peacebuilding. However, relatively fewer (26% less) women have smartphones compared to men. As a result, digital skills and literacy are also lower. In order to combat this, women must have improved access to technology, and especially internet technology. An interesting solution that is proposed in the session for unpaid/domestic work (5.4) is to use robots as a network of internet towers, a mesh network. In this situation, the Avatar Robots would function as a network of routers that provide the area in which they operate access to the internet. If there are sufficient robots present, this can be a promising trait of Avatar Robots to help people, especially women, get and stay connected over the internet.

Furthermore, Avatar Robots can be used to reduce gender norms and stereotypes. In addition to bridging the gap of physical strength between men and women, it is proposed

[3] "In recent years, Member States and regional organizations have begun establishing networks of women mediators, who are involved at different levels of peace processes. They provide pools of experts who can contribute to peace processes and can also be available for senior appointment by Member States, regional organizations and the United Nations." From: https://peacemaker.un.org/women-mediator-networks

that a gender-neutral appearance of the Avatar Robot may reduce gender stereotypes. Since the robots do not necessitate a gender, they can be represented as gender neutral. This can reduce bias (stereotypes) as well as conflicts about dress code. This can provide great value towards achieving women's emancipation.

In relation to this, Avatar Robots allow for sharing of informal care with a larger group of people. Through telepresence, more people can contribute to informal care of family members. This reduces the load and responsibility of the family member that lives closest by and can also reduce loneliness of those in need of care. For example, people working in other countries can efficiently visit their family at home and provide a helping hand.

4.5 Visionary applications

There are more, interesting approaches to achieving impact with Avatar Robots that are less suitable for categorisation. However, these visionary approaches are key to this brainstorm session and are important to mention. Therefore, in this section we will highlight the most innovative, visionary applications of Avatar Robots.

Firstly, in the brainstorm for sustainable production/consumption (12.1), the idea was proposed that inmates could work outside of their cell complexes. For example, they could use (monitored) Avatar systems to collect garbage, clean beaches and fulfil other community services. Closely connected to this, is that teenagers can do similar voluntary work in their leftover time. In general, the key is that community service can be extended to remote locations where the aid is more necessary. In this way, human labour can be spread across the world, and places in need can receive quick help. Additionally, it may motivate those doing the community services by the social and environmental purpose added to their task. The experience of contribution may be larger when helping out poor areas, than when picking up litter from the streets in a developed city.

Furthermore, sub-SDG 5.4 also addresses the problem that little to no value is attached to unpaid/domestic work. In the previous sections, most thoughts have been directed to making these unvalued tasks more efficient. Another creative solution to this may be household attachments for the Avatar Robot that can simplify chores. For example, a robot may be able to use different modules for different household tasks. However, there is more that can be done than make the tasks more efficient. An Avatar Robot can also credit the unpaid work, as these can register the time and effort that is invested into the work. Integration of such a valuing system may increase insight in the amount of time invested per

family, and how this can be redistributed for balance among family members. Additionally, it may allow for appropriate compensation for otherwise unregistered work.

Also, unpaid and domestic work can be made more engaging and fun using Avatar Robots. For example, chores can benefit from use of Augmented Reality features to gamify mundane tasks. This makes doing the activity more engaging and might draw interest to doing the activity. In addition to making informal care more accessible for families (Section 4.4), it can also be made more fun and engaging. In contrast to visiting (grand-)parents in need of informal care, these elderly may benefit from the physical capabilities of Avatar Robots. For example, through operating an Avatar Robot, they may more easily participate in more physically demanding activities such as hikes and games. This can reduce the age gap between family members and improve their relationship.

4.6 Concerning applications

These results from the brainstorm selection have been categorised as concerning avenues because these results directly evoked critical and concerned responses in the session when other participants read them. In other words, their association with such a scenario was negative, rather than positive like the other scenarios. Furthermore, these scenarios are an illustration of the statement in the Introduction of this research: It cannot be taken for granted that good intentions create only positive impact. These concerning scenarios are an example of this.

The first example of this is that Avatar Robots can allow for remote caretaking for babies. In this example, it was proposed to be able to change a baby's diaper remotely. However, the response to this was that it would distance ourselves from the human aspect of care too much. Taking care of a baby using a robot was perceived as inhumane. However, this scenario may be interesting for ethical discussions and/or future forecasts and is therefore included in this research.

Furthermore, Avatar Robots could be used to enable women to keep working during pregnancy. Since an Avatar Robot reduces physical strain on the human body, a pregnant woman would be able to continue working without the physical exhaustion. However, during the session it was quickly expressed that this may lead to an adverse effect. One of the participants mentioned to know that maternity leave benefits women's participation in the labour force, arguing that proper employee's rights increase the chance of the pregnant woman not quitting or losing their job.

5 DISCUSSION

In this section, the major findings of the research will be highlighted along with their implications. Furthermore, these results are compared to the results from the technology-driven approach in Chapter 2. Particular focus goes to the breadth and type of results that are introduced. Additionally, the limitations of this research are highlighted and suggestions for further research are proposed.

The results from the technology-driven approach and the impact-driven approach are combined into a comprehensive diagram that can be retrieved in full in Appendix 7.3. The intention of this diagram is to visualise the progress from abstract (SDG) to concrete (Requirements), this is from left to right in the diagram. Please note that the results that are only found in the impact-driven approach (brainstorm) are marked as blue circles. The concerns that are identified have a red ring, and the scenarios that were only identified in the technology-driven approach have an orange ring. The first two pages of this appendix contain the results from the impact-driven approach. The third page contains the results from the technology-driven approach. Upon comparison, it becomes evident that there are differences between the two approaches on a macro- and a micro level.

5.1 Macro-level comparison

At a macro level it is clear that the impact-driven approach distinguishes itself from the technology-driven approach by the breadth of the applications. As becomes evident in Figure 3, the applications show that the scenarios can be subcategorized into four categories. In contrast, the SDG's that are analysed in the technology-driven approach have only one or two associated categories or scenarios. This means that the impact-driven approach seems to achieve a broader perspective by nature. This is desirable, as it has become evident that a multi-perspective approach is crucial to achieve a maximum positive impact.

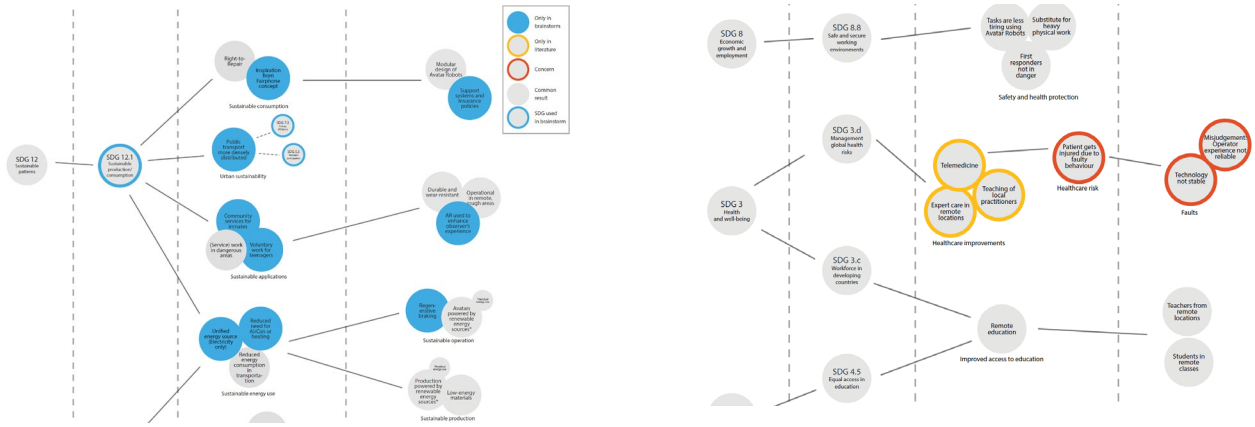

FIGURE 3 – MACRO-LEVEL COMPARISON OF IMPACT-DRIVEN APPROACH (LEFT) AND TECHNOLOGY-DRIVEN APPROACH (RIGHT)

Secondly, it is part of this research to identify potential pitfalls using this overview, and the technology-driven approach shows more results in this regard. From a macro-level analysis, it becomes clear that the literature research has led to more concrete concerns that need addressing. The impact-driven approach has identified two concerns regarding sub-SDG's 5.4 and 5.5, and they are related: Remote care for babies is seen as inhuman, and continuation of work during pregnancy is believed to reduce labour force participation. In contrast, the technology-driven approach has identified many more concerns. This is explained through the fact that there was existing literature found on concerns about Avatar Robots as well as adjacent technologies from which concerns could be extrapolated. Additionally, the brainstorm session was created to generate a positive impact, and we did not actively motivate participants to come up with negative scenarios. However, a similar session designed to brainstorm about concerning scenarios will potentially deliver interesting outcomes in this regard. Therefore, exploring this avenue is highly recommended for future researchers to pursue to add more potential pitfalls to the overview.

Lastly, the analysis of the technology-driven approach shows fewer concrete design requirements. This is explained by the fact that this analysis of impact has been done by connecting the applications found in literature directly to the SDG's. In this approach, fewer concrete requirements are considered. Therefore, this difference must be interpreted with caution. Regardless, the findings do show that the impact-driven approach has depth in addition to the breadth.

5.2 Micro-level comparison

On a micro-level we analyse the content of the diagrams to identify the overlap and differences between the two approaches. The results show that the most creative scenarios, especially those mentioned in Section 4.5, surpass what is found in Chapter 2. The brainstorm session adds to these insights with concepts such as, modularity and repairability, Avatar system efficiency through waste energy, gender neutrality and specific capabilities such as water- and fireproofing. The most innovative sections of the brainstorm session are linked to sub-SDG's 5.4 (Unpaid/Domestic Care), 5.5 (Women's participation) and 13.1 (Climate Change Adaptation).

Firstly, regarding sub-SDG's 5.4 and 5.5, a lot of previously unheard-of scenarios were invented as a way for Avatar Robots to play a role in women empowerment and the reduction gender norms. This is a link that was not previously identified in existing literature, but a lot of examples are imagined where there is a benefit to be had. More specifically, Avatar Robots could be used as a system to assign value to domestic care work through registering the amount of time invested into it. Additionally, household chores can be gamified in the VR environment to make them more enjoyable, and household attachment modules can make an efficient, specifically designed home-care Avatar Robot. Additionally, it was found in both approaches that the introduction of Avatar Robots can have a beneficial effect on sharing informal care among more family members: Remote family members can quickly visit and help out. However, in the brainstorm this idea was turned around into something more interesting. Family members that are less mobile can join physical and/or remote activities through Avatar Robots. The last innovative additions to these topics that is found in the impact-driven approach are that a gender-neutral appearance of the Avatar Robot should have an impact on the reduction of gender norms, and that the strength-gap between men and women is no longer relevant through teleoperation. This means that selection can transition to solely being based on skill, and not gender or physique.

Secondly, the session on sub-SDG 13.1 yielded some heroic scenarios for Avatar Robots, as identified in Section 4.5. These scenarios are combined with requirements such as repairability and modular design to make a durable Avatar ecosystem that can withstand environmental disasters and protect first responders in doing their jobs. This can have a large effect on how an Avatar Robot may be treated, and therefore where it can be put to use. This increases the possibility for a positive impact. Furthermore, it is also deemed resource-efficient to repair a system in Section 4.2. This is an example of how ripple effects may occur, and this pattern has become evident in the brainstorm session (see Appendix 7.3).

The results show that the impact-driven approach delivers interesting additions to the technology-driven approach. However, there is also a lot of common ground between the two approaches and their results. The diagrams consist of a lot of just grey circles. This indicates that the scenario or requirement is common, found in both approaches. The contents of these scenarios and requirements are often fairly straightforward and based on engineering background. The result of this is a more traditional perspective towards innovation. This traditional perspective is in line with what has been found in the technology-driven approach in Chapter 2. For example, [4] mentions "protecting human live by exposition to danger", an application which is also highlighted in Section 4.3. Additionally, the applications illustrated by [4] include time and resource efficiency for industrial (maintenance purposes) as well, which is similar to the input as shown in Sections 4.1 and 4.2. Furthermore, there is frequent overlap between the design guidelines concerning dexterity of the Avatar Robot, networking options, security, sensory reality, accessibility and autonomy. In addition to this, the requirements wide accessibility, intuitive operation, fine motoric skills and real-time operation make a return for almost every scenario. In the diagrams these have not repeatedly been put at every section, but only at the most relevant ones. It should be noted that this is done subjectively. Regardless, the generality of these requirements is an indication that these requirements are a necessity for the ecosystem of Avatar Robots to be implemented well.

5.3 Meaning of the findings

The technology-driven approach is the more common approach to analyse impact. For this reason, it is interesting to look at the differences between this traditional approach and the impact-driven approach. Most important is the inclusion of concepts that may potentially be missed if only the technology-driven approach is used, as in [4], for example.

The macro-level comparison shows that the results from the impact-driven approach are broader and more concrete, and the micro-level comparison shows that there are novel concepts being introduced as new applications for Avatar Robots. From these results it can be concluded that the brainstorm method may pose as an attractive addition to traditional technology-driven approaches. The impact-driven approach presents itself as an effective way to generate a broad selection of scenarios and requirements that are aimed to maximise impact on the most catalytic sub-SDG's. However, the results from this brainstorm session are not all-encompassing, but provide relevant and new perspectives. Therefore, these

results are best used as an inspiration, a starting point and a proof of concept for the more inclusive impact-driven approach.

Additionally, this brainstorm method is likely very suitable for inclusion of people with little to no background knowledge. This is because it speaks to a participant's imagination rather than their engineering knowledge. This is very beneficial because it means that participation is very accessible, anyone can contribute.

We recommend repeating this impact-driven approach with more stakeholders. Moreover, it could be regarded as strategic to include perspectives from the (interested) layman. According to [18], the inclusion of broad perspectives may lead to interesting new concepts.

5.4 Limitations

The first and foremost limitation to this research has been in the execution of the brainstorm session. This first round has been done in a small bubble of participants from the UT. In order to fully cover a multi-perspective overview, many more, different perspectives need to be included. For example, exposure to the creative sector may introduce highly creative interpretations and possibilities for Avatar Robots that may not be discovered with a more traditional, scientific perspective. This is part of the value of Wijze Processen that is introduced in [18].

Furthermore, the categorisation and organisation of the brainstorm results has been done by the researchers alone. Although we have fed back the categorised outcomes to some of the participants, and received approval for this, it was sometimes difficult to fully grasp what a short sentence meant in full. For this reason, this analysis is subject to the researcher's interpretation and that is a potential weakness. In order to make the full process of the brainstorm more inclusive, it is proposed to include this analysis phase as a final round in the brainstorm session.

Moreover, a remark has to be made about the work-from-home implementation of this research. In order to comply with the changing Coronavirus regulations that are put up by the Dutch national government, the decision was made to do every aspect in a virtual setting. This meant that the brainstorm had to be converted to an online workspace. It is not confirmed, but it may have had an influence on the interaction and level of input that the participants have given. It is, at this point, not certain whether this has had a positive or a negative influence, but the situation is worth mentioning regardless.

Also, the literature analysis of this research is only of a limited size. Given the time and resource constraints of this research, a finite, small amount of literature research could realistically be done. For this reason, there are potentially more applications than what has been identified in this research. It should be known that it cannot be confirmed that the applications identified in Chapter 2 are the best or most well fitting for this research. A potential future research avenue for this is to do a larger literature analysis and categorize this into applications. With this information, the system analysis by [25] can be applied to Avatar Robots as a process to score impact. The result could be a literature-based large quantity overview of the impact of Avatar Robots on the SDG's.

Lastly, it is important to be aware of the context of the analysis by [25]. It should be noted that the findings by [25] are not all-inclusive or meant as a method for scientific assessment. Rather, it is intended to be used as a tool that supports policy making, with a high degree of transparency and opportunity for engagement. It is intended to help kickstart a way of working with the SDG's as an interactive system. Furthermore, it should be noted that this research is based on the context of Sweden in 2018. The analysis and final outcomes are subject to deficiencies in the scoring approach (where the SDG's have been given a rating based on their positive or negative impact). This scoring process is judgement-based and has been done with limited in-house resources. Therefore, this analysis may not coincide with an accurate representation of other societies or locations around the world. With acknowledgement of the value of Wijze Transparantie in [18], it is imperative to highlight the context of this reference. Regardless, it does present a fruitful foundation to work with for the purpose of identifying the most catalytic sub-SDG's.

5.5 Reflection

In the starting phase, there was no clear idea of how to approach the creation of an overview of the impact of Avatar Robots on society using the SDG's. Therefore, the process of this research has been very dynamic. It was difficult to come up with a concrete plan for the best approach on how to tackle this. Fortunately, we have had personal help from the author of [18], whom has had a crucial role in directing and shaping this process and approach. They have provided guidelines and steered towards a broad starting point. This has been the first indication of a clear goal. Since this research topic is so new, yet so extensive, it is difficult to set a clear end-goal for oneself: When is it complete for this project? This lack of direction made navigating the process difficult at times. However, I have been convinced that a solid starting point is more important than to be all-encompassing and complete. Therefore, the

aim of this research could now be directed to creating the strongest foundation for a bigger overview.

Additionally, the process of the brainstorm session led to some interesting findings. Due to the free-flow nature of the brainstorm session, input is scattered over the workspace. In order to gain a clearer overview, the input provided by the participants has been categorized. These categories reveal either a traditional perspective or more creative and imaginative perspective. This has formed the basis for the concepts “technology-driven approach”, which had substantial overlap with the literature research and “impact-driven approach”, where the new concepts emerged.

As a result of this categorization, it has become evident that the time spent in the brainstorm session can be a factor for creative thinking. In other words, the participants needed to warm up their imagination. The amount of invested creativity in the scenario’s that are created increased as the session went on to discuss the last sub-SDG’s. This means that the sub-SDG that was treated the very last (5.4) had the most innovative scenarios. The order of the SDG’s in the session was not chosen particularly. However, it has proven to provide very interesting new opportunities for sub-SDG 5.4, which did not have any prior impact from Avatar Robots directed to it, before this research. But this does mean that there is potential left for more innovative scenarios in the other SDG’s. Therefore, we recommend including a warm-up phase to the brainstorm session, or to revisit the SDG’s for another round once the participants are accustomed to the workflow.

Lastly, besides the influence of the Coronavirus regulations on the interaction in the brainstorm session, it has also had its influence on this research as a journey. The fact that this project has been done from a home environment meant that it was more difficult to engage in critical discussions on the approach, and the supervisor feedback sessions have been absolutely crucial to the upkeeping of this research. A change in work environment, or an interesting conversation with peers may have led to new insights. Now, this research is largely the fruit of my (the researcher’s) own thoughts, assisted with feedback sessions.

6 CONCLUSION

In this study, we developed an overview of the impact of Avatar Robots on society in applications and concerns through impact on the SDG's. We added to a technology-driven approach, in a literature analysis for direct impact using the SDG's, with an impact-driven approach, in a brainstorm session for maximum impact on catalytic sub-SDG's.

The technology-driven approach yields more straightforward results and treats the SDG's as individual goals. In contrast, the impact-driven approach in the brainstorm session treats the SDG's as a system by inclusion of ripple effects. The brainstorm session has proven to be an effective way to collaborate with multiple perspectives.

This resulted in a broad overview of relevant, innovative applications and requirements for Avatar Robots. In fact, there is some overlap between the two approaches in the scenarios and requirements they lead to, but it is evident that the impact-driven approach leads to more novel concepts and new ideas. It invites a more imaginary perspective, since input inspiration in this approach is less constrained by present technological limitations. Additionally, since it relies less on knowledge of technology, it is also more accessible for less savvy stakeholders to participate at a high level. This adds to the multi-perspective potential of this overview.

The size and scope of this brainstorm session is sufficient to see the benefit as a proof of concept. However, it is important to note that this overview is not all-encompassing or conclusive. The participants' perspectives are still limited to a bubble within the University of Twente. Therefore, it is recommended for future researchers to include more perspectives from various disciplines. In particular, the creative arts industry is recommended as an interesting addition due to the restriction-free, yet socially relevant imagination capacity. Not only does this generate more input, but the input will also likely have more breadth, which is desired in this approach. Additionally, a similar brainstorm could be designed to investigate concern. This approach may provide interesting additions to the overview with regards to concerns that are present in various perspectives on society.

Regardless, this research has created a starting point towards an overview of the impact of Avatar Robots on society using the SDG's. In particular, this research points to the inclusion of multiple disciplines for a broad inclusion of perspectives to maximise positive impact and avoid pitfalls.

7 APPENDICES

7.1 Highlighted list of SDG's

Telemedicine Classroom education Dangerous jobs Remote visiting

Negative impact (concerns)

Sustainable Development Goals

Goal 1. End poverty in all its forms everywhere

Goal 2. End hunger, achieve food security and improved nutrition and promote sustainable agriculture

Goal 3. Ensure healthy lives and promote well-being for all at all ages

Goal 4. Ensure inclusive and equitable quality education and promote lifelong learning opportunities for all

Goal 5. Achieve gender equality and empower all women and girls

Goal 6. Ensure availability and sustainable management of water and sanitation for all

Goal 7. Ensure access to affordable, reliable, sustainable and modern energy for all

Goal 8. Promote sustained, inclusive and sustainable economic growth, full and productive employment and decent work for all

Goal 9. Build resilient infrastructure, promote inclusive and sustainable industrialization and foster innovation

Goal 10. Reduce inequality within and among countries

Goal 11. Make cities and human settlements inclusive, safe, resilient and sustainable

Goal 12. Ensure sustainable consumption and production patterns

Goal 13. Take urgent action to combat climate change and its impacts*

Goal 14. Conserve and sustainably use the oceans, seas and marine resources for sustainable development

Goal 15. Protect, restore and promote sustainable use of terrestrial ecosystems, sustainably manage forests, combat desertification, and halt and reverse land degradation and halt biodiversity loss

Goal 16. Promote peaceful and inclusive societies for sustainable development, provide access to justice for all and build effective, accountable and inclusive institutions at all levels

Goal 17. Strengthen the means of implementation and revitalize the Global Partnership for Sustainable Development

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* Acknowledging that the United Nations Framework Convention on Climate Change is the primary international, intergovernmental forum for negotiating the global response to climate change.

Goal 1. End poverty in all its forms everywhere

1.1 By 2030, eradicate extreme poverty for all people everywhere, currently measured as people living on less than $1.25 a day

1.2 By 2030, reduce at least by half the proportion of men, women and children of all ages living in poverty in all its dimensions according to national definitions

1.3 Implement nationally appropriate social protection systems and measures for all, including floors, and by 2030 achieve substantial coverage of the poor and the vulnerable

1.4 By 2030, ensure that all men and women, in particular the poor and the vulnerable, have equal rights to economic resources, as well as access to basic services, ownership and control over land and other forms of property, inheritance, natural resources, appropriate new technology and financial services, including microfinance

1.5 By 2030, build the resilience of the poor and those in vulnerable situations and reduce their exposure and vulnerability to climate-related extreme events and other economic, social and environmental shocks and disasters

1.a Ensure significant mobilization of resources from a variety of sources, including through enhanced development cooperation, in order to provide adequate and predictable means for developing countries, in particular least developed countries, to implement programmes and policies to end poverty in all its dimensions

1.b Create sound policy frameworks at the national, regional and international levels, based on pro-poor and gender-sensitive development strategies, to support accelerated investment in poverty eradication actions

Goal 2. End hunger, achieve food security and improved nutrition and promote sustainable agriculture

2.1 By 2030, end hunger and ensure access by all people, in particular the poor and people in vulnerable situations, including infants, to safe, nutritious and sufficient food all year round

2.2 By 2030, end all forms of malnutrition, including achieving, by 2025, the internationally agreed targets on stunting and wasting in children under 5 years of age, and address the nutritional needs of adolescent girls, pregnant and lactating women and older persons

2.3 By 2030, double the agricultural productivity and incomes of small-scale food producers, in particular women, indigenous peoples, family farmers, pastoralists and fishers, including through secure and equal access to land, other productive resources and inputs, knowledge, financial services, markets and opportunities for value addition and non-farm employment

2.4 By 2030, ensure sustainable food production systems and implement resilient agricultural practices that increase productivity and production, that help maintain ecosystems, that strengthen capacity for adaptation to climate change, extreme weather, drought, flooding and other disasters and that progressively improve land and soil quality

2.5 By 2020, maintain the genetic diversity of seeds, cultivated plants and farmed and domesticated animals and their related wild species, including through soundly managed and

diversified seed and plant banks at the national, regional and international levels, and promote access to and fair and equitable sharing of benefits arising from the utilization of genetic resources and associated traditional knowledge, as internationally agreed

2.a Increase investment, including through enhanced international cooperation, in rural infrastructure, agricultural research and extension services, technology development and plant and livestock gene banks in order to enhance agricultural productive capacity in developing countries, in particular least developed countries

2.b Correct and prevent trade restrictions and distortions in world agricultural markets, including through the parallel elimination of all forms of agricultural export subsidies and all export measures with equivalent effect, in accordance with the mandate of the Doha Development Round

2.c Adopt measures to ensure the proper functioning of food commodity markets and their derivatives and facilitate timely access to market information, including on food reserves, in order to help limit extreme food price volatility

Goal 3. Ensure healthy lives and promote well-being for all at all ages

3.1 By 2030, reduce the global maternal mortality ratio to less than 70 per 100,000 live births

3.2 By 2030, end preventable deaths of newborns and children under 5 years of age, with all countries aiming to reduce neonatal mortality to at least as low as 12 per 1,000 live births and under-5 mortality to at least as low as 25 per 1,000 live births

3.3 By 2030, end the epidemics of AIDS, tuberculosis, malaria and neglected tropical diseases and combat hepatitis, water-borne diseases and other communicable diseases

3.4 By 2030, reduce by one third premature mortality from non-communicable diseases through prevention and treatment and promote mental health and well-being

3.5 Strengthen the prevention and treatment of substance abuse, including narcotic drug abuse and harmful use of alcohol

3.6 By 2020, halve the number of global deaths and injuries from road traffic accidents

3.7 By 2030, ensure universal access to sexual and reproductive health-care services, including for family planning, information and education, and the integration of reproductive health into national strategies and programmes

3.8 Achieve universal health coverage, including financial risk protection, access to quality essential health-care services and access to safe, effective, quality and affordable essential medicines and vaccines for all

3.9 By 2030, substantially reduce the number of deaths and illnesses from hazardous chemicals and air, water and soil pollution and contamination

3.a Strengthen the implementation of the World Health Organization Framework Convention on Tobacco Control in all countries, as appropriate

3.b Support the research and development of vaccines and medicines for the communicable and non-communicable diseases that primarily affect developing countries, provide access to affordable essential medicines and vaccines, in accordance with the Doha Declaration on the TRIPS Agreement and Public Health, which affirms the right of developing countries to use to the full the provisions in the Agreement on Trade-Related Aspects of Intellectual Property Rights regarding flexibilities to protect public health, and, in particular, provide access to medicines for all

3.c Substantially increase health financing and the recruitment, development, training and retention of the health workforce in developing countries, especially in least developed countries and small island developing States

3.d Strengthen the capacity of all countries, in particular developing countries, for early warning, risk reduction and management of national and global health risks

Goal 4. Ensure inclusive and equitable quality education and promote lifelong learning opportunities for all

4.1 By 2030, ensure that all girls and boys complete free, equitable and quality primary and secondary education leading to relevant and effective learning outcomes

4.2 By 2030, ensure that all girls and boys have access to quality early childhood development, care and pre-primary education so that they are ready for primary education

4.3 By 2030, ensure equal access for all women and men to affordable and quality technical, vocational and tertiary education, including university

4.4 By 2030, substantially increase the number of youth and adults who have relevant skills, including technical and vocational skills, for employment, decent jobs and entrepreneurship

4.5 By 2030, eliminate gender disparities in education and ensure equal access to all levels of education and vocational training for the vulnerable, including persons with disabilities, indigenous peoples and children in vulnerable situations

4.6 By 2030, ensure that all youth and a substantial proportion of adults, both men and women, achieve literacy and numeracy

4.7 By 2030, ensure that all learners acquire the knowledge and skills needed to promote sustainable development, including, among others, through education for sustainable development and sustainable lifestyles, human rights, gender equality, promotion of a culture of peace and non-violence, global citizenship and appreciation of cultural diversity and of culture's contribution to sustainable development

4.a Build and upgrade education facilities that are child, disability and gender sensitive and provide safe, non-violent, inclusive and effective learning environments for all

4.b By 2020, substantially expand globally the number of scholarships available to developing countries, in particular least developed countries, small island developing States and African countries, for enrolment in higher education, including vocational training and

information and communications technology, technical, engineering and scientific programmes, in developed countries and other developing countries

4.c By 2030, substantially increase the supply of qualified teachers, including through international cooperation for teacher training in developing countries, especially least developed countries and small island developing States

Goal 5. Achieve gender equality and empower all women and girls

5.1 End all forms of discrimination against all women and girls everywhere

5.2 Eliminate all forms of violence against all women and girls in the public and private spheres, including trafficking and sexual and other types of exploitation

5.3 Eliminate all harmful practices, such as child, early and forced marriage and female genital mutilation

5.4 Recognize and value unpaid care and domestic work through the provision of public services, infrastructure and social protection policies and the promotion of shared responsibility within the household and the family as nationally appropriate

5.5 Ensure women's full and effective participation and equal opportunities for leadership at all levels of decision-making in political, economic and public life

5.6 Ensure universal access to sexual and reproductive health and reproductive rights as agreed in accordance with the Programme of Action of the International Conference on Population and Development and the Beijing Platform for Action and the outcome documents of their review conferences

5.a Undertake reforms to give women equal rights to economic resources, as well as access to ownership and control over land and other forms of property, financial services, inheritance and natural resources, in accordance with national laws

5.b Enhance the use of enabling technology, in particular information and communications technology, to promote the empowerment of women

5.c Adopt and strengthen sound policies and enforceable legislation for the promotion of gender equality and the empowerment of all women and girls at all levels

Goal 6. Ensure availability and sustainable management of water and sanitation for all

6.1 By 2030, achieve universal and equitable access to safe and affordable drinking water for all

6.2 By 2030, achieve access to adequate and equitable sanitation and hygiene for all and end open defecation, paying special attention to the needs of women and girls and those in vulnerable situations

6.3 By 2030, improve water quality by reducing pollution, eliminating dumping and minimizing release of hazardous chemicals and materials, halving the proportion of untreated wastewater and substantially increasing recycling and safe reuse globally

6.4 By 2030, substantially increase water-use efficiency across all sectors and ensure sustainable withdrawals and supply of freshwater to address water scarcity and substantially reduce the number of people suffering from water scarcity

6.5 By 2030, implement integrated water resources management at all levels, including through transboundary cooperation as appropriate

6.6 By 2020, protect and restore water-related ecosystems, including mountains, forests, wetlands, rivers, aquifers and lakes

6.a By 2030, expand international cooperation and capacity-building support to developing countries in water- and sanitation-related activities and programmes, including water harvesting, desalination, water efficiency, wastewater treatment, recycling and reuse technologies

6.b Support and strengthen the participation of local communities in improving water and sanitation management

Goal 7. Ensure access to affordable, reliable, sustainable and modern energy for all

7.1 By 2030, ensure universal access to affordable, reliable and modern energy services

7.2 By 2030, increase substantially the share of renewable energy in the global energy mix

7.3 By 2030, double the global rate of improvement in energy efficiency

7.a By 2030, enhance international cooperation to facilitate access to clean energy research and technology, including renewable energy, energy efficiency and advanced and cleaner fossil-fuel technology, and promote investment in energy infrastructure and clean energy technology

7.b By 2030, expand infrastructure and upgrade technology for supplying modern and sustainable energy services for all in developing countries, in particular least developed countries, small island developing States and landlocked developing countries, in accordance with their respective programmes of support

Goal 8. Promote sustained, inclusive and sustainable economic growth, full and productive employment and decent work for all

8.1 Sustain per capita economic growth in accordance with national circumstances and, in particular, at least 7 per cent gross domestic product growth per annum in the least developed countries

8.2 Achieve higher levels of economic productivity through diversification, technological upgrading and innovation, including through a focus on high-value added and labour-intensive sectors

8.3 Promote development-oriented policies that support productive activities, decent job creation, entrepreneurship, creativity and innovation, and encourage the formalization and growth of micro-, small- and medium-sized enterprises, including through access to financial services

8.4 Improve progressively, through 2030, global resource efficiency in consumption and production and endeavour to decouple economic growth from environmental degradation, in accordance with the 10-Year Framework of Programmes on Sustainable Consumption and Production, with developed countries taking the lead

8.5 By 2030, achieve full and productive employment and decent work for all women and men, including for young people and persons with disabilities, and equal pay for work of equal value

8.6 By 2020, substantially reduce the proportion of youth not in employment, education or training

8.7 Take immediate and effective measures to eradicate forced labour, end modern slavery and human trafficking and secure the prohibition and elimination of the worst forms of child labour, including recruitment and use of child soldiers, and by 2025 end child labour in all its forms

8.8 Protect labour rights and promote safe and secure working environments for all workers, including migrant workers, in particular women migrants, and those in precarious employment

8.9 By 2030, devise and implement policies to promote sustainable tourism that creates jobs and promotes local culture and products

8.10 Strengthen the capacity of domestic financial institutions to encourage and expand access to banking, insurance and financial services for all

8.a Increase Aid for Trade support for developing countries, in particular least developed countries, including through the Enhanced Integrated Framework for Trade-related Technical Assistance to Least Developed Countries

8.b By 2020, develop and operationalize a global strategy for youth employment and implement the Global Jobs Pact of the International Labour Organization

Goal 9. Build resilient infrastructure, promote inclusive and sustainable industrialization and foster innovation

9.1 Develop quality, reliable, sustainable and resilient infrastructure, including regional and transborder infrastructure, to support economic development and human well-being, with a focus on affordable and equitable access for all

9.2 Promote inclusive and sustainable industrialization and, by 2030, significantly raise industry's share of employment and gross domestic product, in line with national circumstances, and double its share in least developed countries

9.3 Increase the access of small-scale industrial and other enterprises, in particular in developing countries, to financial services, including affordable credit, and their integration into value chains and markets

9.4 By 2030, upgrade infrastructure and retrofit industries to make them sustainable, with increased resource-use efficiency and greater adoption of clean and environmentally sound

technologies and industrial processes, with all countries taking action in accordance with their respective capabilities

9.5 Enhance scientific research, upgrade the technological capabilities of industrial sectors in all countries, in particular developing countries, including, by 2030, encouraging innovation and substantially increasing the number of research and development workers per 1 million people and public and private research and development spending

9.a Facilitate sustainable and resilient infrastructure development in developing countries through enhanced financial, technological and technical support to African countries, least developed countries, landlocked developing countries and small island developing States

9.b Support domestic technology development, research and innovation in developing countries, including by ensuring a conducive policy environment for, inter alia, industrial diversification and value addition to commodities

9.c Significantly increase access to information and communications technology and strive to provide universal and affordable access to the Internet in least developed countries by 2020

Goal 10. Reduce inequality within and among countries

10.1 By 2030, progressively achieve and sustain income growth of the bottom 40 per cent of the population at a rate higher than the national average

10.2 By 2030, empower and promote the social, economic and political inclusion of all, irrespective of age, sex, disability, race, ethnicity, origin, religion or economic or other status

10.3 Ensure equal opportunity and reduce inequalities of outcome, including by eliminating discriminatory laws, policies and practices and promoting appropriate legislation, policies and action in this regard

10.4 Adopt policies, especially fiscal, wage and social protection policies, and progressively achieve greater equality

10.5 Improve the regulation and monitoring of global financial markets and institutions and strengthen the implementation of such regulations

10.6 Ensure enhanced representation and voice for developing countries in decision-making in global international economic and financial institutions in order to deliver more effective, credible, accountable and legitimate institutions

10.7 Facilitate orderly, safe, regular and responsible migration and mobility of people, including through the implementation of planned and well-managed migration policies

10.a Implement the principle of special and differential treatment for developing countries, in particular least developed countries, in accordance with World Trade Organization agreements

10.b Encourage official development assistance and financial flows, including foreign direct investment, to States where the need is greatest, in particular least developed countries,

African countries, small island developing States and landlocked developing countries, in accordance with their national plans and programmes

10.c By 2030, reduce to less than 3 per cent the transaction costs of migrant remittances and eliminate remittance corridors with costs higher than 5 per cent

Goal 11. Make cities and human settlements inclusive, safe, resilient and sustainable

11.1 By 2030, ensure access for all to adequate, safe and affordable housing and basic services and upgrade slums

11.2 By 2030, provide access to safe, affordable, accessible and sustainable transport systems for all, improving road safety, notably by expanding public transport, with special attention to the needs of those in vulnerable situations, women, children, persons with disabilities and older persons

11.3 By 2030, enhance inclusive and sustainable urbanization and capacity for participatory, integrated and sustainable human settlement planning and management in all countries

11.4 Strengthen efforts to protect and safeguard the world's cultural and natural heritage

11.5 By 2030, significantly reduce the number of deaths and the number of people affected and substantially decrease the direct economic losses relative to global gross domestic product caused by disasters, including water-related disasters, with a focus on protecting the poor and people in vulnerable situations

11.6 By 2030, reduce the adverse per capita environmental impact of cities, including by paying special attention to air quality and municipal and other waste management

11.7 By 2030, provide universal access to safe, inclusive and accessible, green and public spaces, in particular for women and children, older persons and persons with disabilities

11.a Support positive economic, social and environmental links between urban, peri-urban and rural areas by strengthening national and regional development planning

11.b By 2020, substantially increase the number of cities and human settlements adopting and implementing integrated policies and plans towards inclusion, resource efficiency, mitigation and adaptation to climate change, resilience to disasters, and develop and implement, in line with the Sendai Framework for Disaster Risk Reduction 2015-2030, holistic disaster risk management at all levels

11.c Support least developed countries, including through financial and technical assistance, in building sustainable and resilient buildings utilizing local materials

Goal 12. Ensure sustainable consumption and production patterns

12.1 Implement the 10-Year Framework of Programmes on Sustainable Consumption and Production Patterns, all countries taking action, with developed countries taking the lead, taking into account the development and capabilities of developing countries

12.2 By 2030, achieve the sustainable management and efficient use of natural resources

12.3 By 2030, halve per capita global food waste at the retail and consumer levels and reduce food losses along production and supply chains, including post-harvest losses

12.4 By 2020, achieve the environmentally sound management of chemicals and all wastes throughout their life cycle, in accordance with agreed international frameworks, and significantly reduce their release to air, water and soil in order to minimize their adverse impacts on human health and the environment

12.5 By 2030, substantially reduce waste generation through prevention, reduction, recycling and reuse

12.6 Encourage companies, especially large and transnational companies, to adopt sustainable practices and to integrate sustainability information into their reporting cycle

12.7 Promote public procurement practices that are sustainable, in accordance with national policies and priorities

12.8 By 2030, ensure that people everywhere have the relevant information and awareness for sustainable development and lifestyles in harmony with nature

12.a Support developing countries to strengthen their scientific and technological capacity to move towards more sustainable patterns of consumption and production

12.b Develop and implement tools to monitor sustainable development impacts for sustainable tourism that creates jobs and promotes local culture and products

12.c Rationalize inefficient fossil-fuel subsidies that encourage wasteful consumption by removing market distortions, in accordance with national circumstances, including by restructuring taxation and phasing out those harmful subsidies, where they exist, to reflect their environmental impacts, taking fully into account the specific needs and conditions of developing countries and minimizing the possible adverse impacts on their development in a manner that protects the poor and the affected communities

Goal 13. Take urgent action to combat climate change and its impacts*

13.1 Strengthen resilience and adaptive capacity to climate-related hazards and natural disasters in all countries

13.2 Integrate climate change measures into national policies, strategies and planning

13.3 Improve education, awareness-raising and human and institutional capacity on climate change mitigation, adaptation, impact reduction and early warning

13.a Implement the commitment undertaken by developed-country parties to the United Nations Framework Convention on Climate Change to a goal of mobilizing jointly $100 billion annually by 2020 from all sources to address the needs of developing countries in the context of meaningful mitigation actions and transparency on implementation and fully operationalize the Green Climate Fund through its capitalization as soon as possible

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* Acknowledging that the United Nations Framework Convention on Climate Change is the primary international, intergovernmental forum for negotiating the global response to climate change.

13.b Promote mechanisms for raising capacity for effective climate change-related planning and management in least developed countries and small island developing States, including focusing on women, youth and local and marginalized communities

Goal 14. Conserve and sustainably use the oceans, seas and marine resources for sustainable development

14.1 By 2025, prevent and significantly reduce marine pollution of all kinds, in particular from land-based activities, including marine debris and nutrient pollution

14.2 By 2020, sustainably manage and protect marine and coastal ecosystems to avoid significant adverse impacts, including by strengthening their resilience, and take action for their restoration in order to achieve healthy and productive oceans

14.3 Minimize and address the impacts of ocean acidification, including through enhanced scientific cooperation at all levels

14.4 By 2020, effectively regulate harvesting and end overfishing, illegal, unreported and unregulated fishing and destructive fishing practices and implement science-based management plans, in order to restore fish stocks in the shortest time feasible, at least to levels that can produce maximum sustainable yield as determined by their biological characteristics

14.5 By 2020, conserve at least 10 per cent of coastal and marine areas, consistent with national and international law and based on the best available scientific information

14.6 By 2020, prohibit certain forms of fisheries subsidies which contribute to overcapacity and overfishing, eliminate subsidies that contribute to illegal, unreported and unregulated fishing and refrain from introducing new such subsidies, recognizing that appropriate and effective special and differential treatment for developing and least developed countries should be an integral part of the World Trade Organization fisheries subsidies negotiation[2]

14.7 By 2030, increase the economic benefits to small island developing States and least developed countries from the sustainable use of marine resources, including through sustainable management of fisheries, aquaculture and tourism

14.a Increase scientific knowledge, develop research capacity and transfer marine technology, taking into account the Intergovernmental Oceanographic Commission Criteria and Guidelines on the Transfer of Marine Technology, in order to improve ocean health and to enhance the contribution of marine biodiversity to the development of developing countries, in particular small island developing States and least developed countries

14.b Provide access for small-scale artisanal fishers to marine resources and markets

14.c Enhance the conservation and sustainable use of oceans and their resources by implementing international law as reflected in the United Nations Convention on the Law of

[2] Taking into account ongoing World Trade Organization negotiations, the Doha Development Agenda and the Hong Kong ministerial mandate.

the Sea, which provides the legal framework for the conservation and sustainable use of oceans and their resources, as recalled in paragraph 158 of "The future we want"

Goal 15. Protect, restore and promote sustainable use of terrestrial ecosystems, sustainably manage forests, combat desertification, and halt and reverse land degradation and halt biodiversity loss

15.1 By 2020, ensure the conservation, restoration and sustainable use of terrestrial and inland freshwater ecosystems and their services, in particular forests, wetlands, mountains and drylands, in line with obligations under international agreements

15.2 By 2020, promote the implementation of sustainable management of all types of forests, halt deforestation, restore degraded forests and substantially increase afforestation and reforestation globally

15.3 By 2030, combat desertification, restore degraded land and soil, including land affected by desertification, drought and floods, and strive to achieve a land degradation-neutral world

15.4 By 2030, ensure the conservation of mountain ecosystems, including their biodiversity, in order to enhance their capacity to provide benefits that are essential for sustainable development

15.5 Take urgent and significant action to reduce the degradation of natural habitats, halt the loss of biodiversity and, by 2020, protect and prevent the extinction of threatened species

15.6 Promote fair and equitable sharing of the benefits arising from the utilization of genetic resources and promote appropriate access to such resources, as internationally agreed

15.7 Take urgent action to end poaching and trafficking of protected species of flora and fauna and address both demand and supply of illegal wildlife products

15.8 By 2020, introduce measures to prevent the introduction and significantly reduce the impact of invasive alien species on land and water ecosystems and control or eradicate the priority species

15.9 By 2020, integrate ecosystem and biodiversity values into national and local planning, development processes, poverty reduction strategies and accounts

15.a Mobilize and significantly increase financial resources from all sources to conserve and sustainably use biodiversity and ecosystems

15.b Mobilize significant resources from all sources and at all levels to finance sustainable forest management and provide adequate incentives to developing countries to advance such management, including for conservation and reforestation

15.c Enhance global support for efforts to combat poaching and trafficking of protected species, including by increasing the capacity of local communities to pursue sustainable livelihood opportunities

Goal 16. Promote peaceful and inclusive societies for sustainable development, provide access to justice for all and build effective, accountable and inclusive institutions at all levels

16.1 Significantly reduce all forms of violence and related death rates everywhere

16.2 End abuse, exploitation, trafficking and all forms of violence against and torture of children

16.3 Promote the rule of law at the national and international levels and ensure equal access to justice for all

16.4 By 2030, significantly reduce illicit financial and arms flows, strengthen the recovery and return of stolen assets and combat all forms of organized crime

16.5 Substantially reduce corruption and bribery in all their forms

16.6 Develop effective, accountable and transparent institutions at all levels

16.7 Ensure responsive, inclusive, participatory and representative decision-making at all levels

16.8 Broaden and strengthen the participation of developing countries in the institutions of global governance

16.9 By 2030, provide legal identity for all, including birth registration

16.10 Ensure public access to information and protect fundamental freedoms, in accordance with national legislation and international agreements

16.a Strengthen relevant national institutions, including through international cooperation, for building capacity at all levels, in particular in developing countries, to prevent violence and combat terrorism and crime

16.b Promote and enforce non-discriminatory laws and policies for sustainable development

Goal 17. Strengthen the means of implementation and revitalize the Global Partnership for Sustainable Development

Finance

17.1 Strengthen domestic resource mobilization, including through international support to developing countries, to improve domestic capacity for tax and other revenue collection

17.2 Developed countries to implement fully their official development assistance commitments, including the commitment by many developed countries to achieve the target of 0.7 per cent of gross national income for official development assistance (ODA/GNI) to developing countries and 0.15 to 0.20 per cent of ODA/GNI to least developed countries; ODA providers are encouraged to consider setting a target to provide at least 0.20 per cent of ODA/GNI to least developed countries

17.3 Mobilize additional financial resources for developing countries from multiple sources

17.4 Assist developing countries in attaining long-term debt sustainability through coordinated policies aimed at fostering debt financing, debt relief and debt restructuring, as appropriate, and address the external debt of highly indebted poor countries to reduce debt distress

17.5 Adopt and implement investment promotion regimes for least developed countries

Technology

17.6 Enhance North-South, South-South and triangular regional and international cooperation on and access to science, technology and innovation and enhance knowledge sharing on mutually agreed terms, including through improved coordination among existing mechanisms, in particular at the United Nations level, and through a global technology facilitation mechanism

17.7 Promote the development, transfer, dissemination and diffusion of environmentally sound technologies to developing countries on favourable terms, including on concessional and preferential terms, as mutually agreed

17.8 Fully operationalize the technology bank and science, technology and innovation capacity-building mechanism for least developed countries by 2017 and enhance the use of enabling technology, in particular information and communications technology

Capacity-building

17.9 Enhance international support for implementing effective and targeted capacity-building in developing countries to support national plans to implement all the Sustainable Development Goals, including through North-South, South-South and triangular cooperation

Trade

17.10 Promote a universal, rules-based, open, non-discriminatory and equitable multilateral trading system under the World Trade Organization, including through the conclusion of negotiations under its Doha Development Agenda

17.11 Significantly increase the exports of developing countries, in particular with a view to doubling the least developed countries' share of global exports by 2020

17.12 Realize timely implementation of duty-free and quota-free market access on a lasting basis for all least developed countries, consistent with World Trade Organization decisions, including by ensuring that preferential rules of origin applicable to imports from least developed countries are transparent and simple, and contribute to facilitating market access

Systemic issues

Policy and institutional coherence

17.13 Enhance global macroeconomic stability, including through policy coordination and policy coherence

17.14 Enhance policy coherence for sustainable development

17.15 Respect each country's policy space and leadership to establish and implement policies for poverty eradication and sustainable development

Multi-stakeholder partnerships

17.16 Enhance the Global Partnership for Sustainable Development, complemented by multi-stakeholder partnerships that mobilize and share knowledge, expertise, technology and financial resources, to support the achievement of the Sustainable Development Goals in all countries, in particular developing countries

17.17 Encourage and promote effective public, public-private and civil society partnerships, building on the experience and resourcing strategies of partnerships

Data, monitoring and accountability

17.18 By 2020, enhance capacity-building support to developing countries, including for least developed countries and small island developing States, to increase significantly the availability of high-quality, timely and reliable data disaggregated by income, gender, age, race, ethnicity, migratory status, disability, geographic location and other characteristics relevant in national contexts

17.19 By 2030, build on existing initiatives to develop measurements of progress on sustainable development that complement gross domestic product, and support statistical capacity-building in developing countries

Means of implementation and the Global Partnership

60. We reaffirm our strong commitment to the full implementation of this new Agenda. We recognize that we will not be able to achieve our ambitious Goals and targets without a revitalized and enhanced Global Partnership and comparably ambitious means of implementation. The revitalized Global Partnership will facilitate an intensive global engagement in support of implementation of all the Goals and targets, bringing together Governments, civil society, the private sector, the United Nations system and other actors and mobilizing all available resources.

61. The Agenda's Goals and targets deal with the means required to realize our collective ambitions. The means of implementation targets under each Sustainable Development Goal and Goal 17, which are referred to above, are key to realizing our Agenda and are of equal importance with the other Goals and targets. We shall accord them equal priority in our implementation efforts and in the global indicator framework for monitoring our progress.

62. This Agenda, including the Sustainable Development Goals, can be met within the framework of a revitalized Global Partnership for Sustainable Development, supported by the

7.2 Brainstorm session results in Miro

SDG 7.3: Energy Efficiency

By 2030, double the global rate of improvement in energy efficiency

Efficiency is using less energy to perform the same task. Improving energy efficiency is often seen as the cheapest way to reduce the use of fossil fuels.

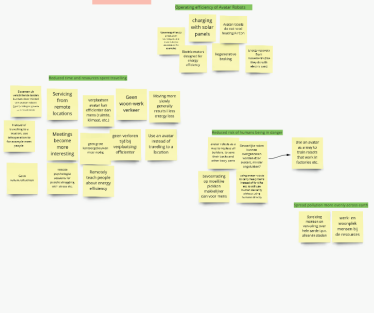
- How can Avatar Robots (help) make buildings, powerplants, vehicles, freight and vehicles more efficient?
- How can Avatar Robots help people to be more efficient? (motivate, help, replace)
- How can Avatar Robots function more efficiently?
- How can we learn from nature's efficiency?

According to simple aerodynamics, bumblebees are too heavy to fly. However, by creating air vortexes under their wings, they generate extra lift, and can fly. Source

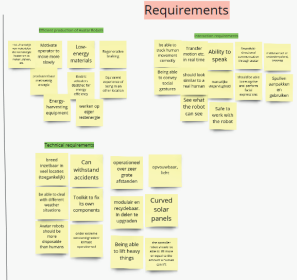
From: https://www.eesi.org/topics/energy-efficiency/description

Session 1 Question: How can Avatar Robots play a role in progressing on SDG 7.3: Energy Efficiency?

Scenarios



Requirements



SDG 5.5: Women's Participation

Ensure women's full and effective participation and equal opportunities for leadership at all levels.

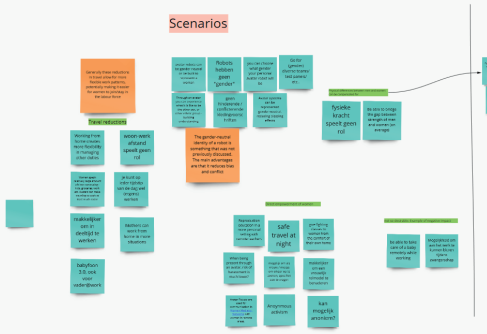
Technology can prove to be an effective organizing tool to progress towards peace. It can enable women and girls to participate in democracy, civic action and peacebuilding. However, relatively fewer (26% less) women tend to have smartphones compared to men. Digital skills and literacy are therefore also lower.

- How can Avatar Robots empower (working) mothers?
- How can Avatar Robots improve women's digital literacy (and programming)?
- How can Avatar Robots help women protect themselves?
- How can Avatar Robots promote human dignity and gender equality?
- How can Avatar Robots protect and promote diversity and inclusiveness?
- *Also consider improvements to be made in development of Avatar Robots!*

From: https://www.usip.org/publications/2019/07/how-women-are-using-technology-advance-gender-equality-and-peace and https://en.unesco.org/artificial-intelligence/gender

Session 2 Question: How can Avatar Robots play a role in progressing on SDG 5.5: Women's Participation?

Scenarios



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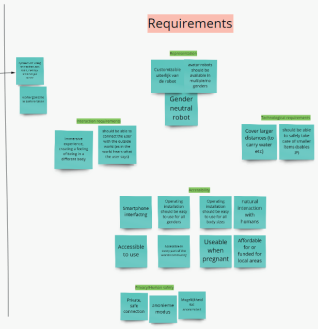


SDG 13.1: Climate Change Adaptation

Strengthen resilience and adaptive capacity to climate-related hazards and natural disasters in all countries

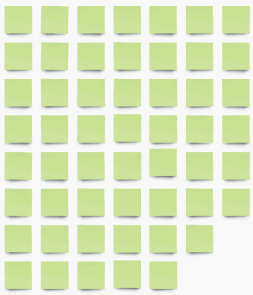
Implement action to respond to the impacts of climate change as well as prepare for future impacts.

Adaptation action should follow a country-driven, gender-responsive, participatory and fully transparent approach that considers vulnerable groups, communities and ecosystems. It should be based on science and traditional knowledge, knowledge of indigenous peoples and knowledge systems.

- How can Avatar Robots be used to improve adaptation/resilience w.r.t. climate change?
- How can Avatar Robots help with the global scale of this issue?

From: https://unfccc.int/topics/adaptation-and-resilience/the-big-picture/what-do-adaptation-to-climate-change-and-climate-resilience-mean

Session 3 Question: How can Avatar Robots play a role in progressing on SDG 13.1: Climate Change Adaptation?



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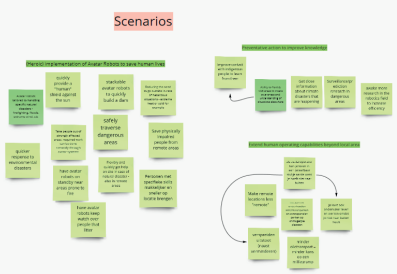

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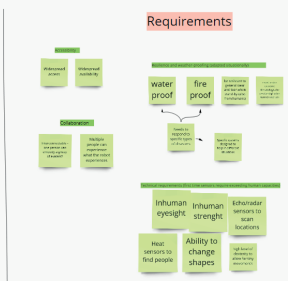


SDG 12.1: Sustainable Consumption/Production

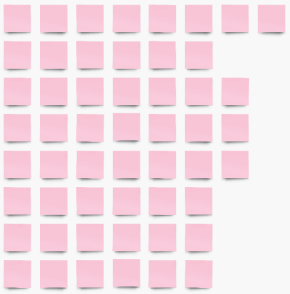
Sustainable consumption and production is about doing more and better with less. It is also about decoupling economic growth from environmental degradation, increasing resource efficiency and promoting sustainable lifestyles.

EKOenergy is a worldwide non-profit ecolabel. In order to qualify, power plants must be both renewable and must meet additional environmental requirements.

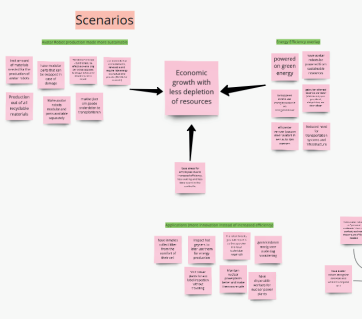
- How can Avatar Robots play a role for the EKOenergy ecolabel?
- How can Avatar Robots be designed sustainably?
- How can Avatar Robots reduce product waste or increase efficiency in other systems? (Food, electronics, production materials?
- Also consider improvements to be made in development of Avatar Robots!

From: https://www.un.org/sustainabledevelopment/sustainable-consumption-production/

Session 4 Question: How can Avatar Robots play a role in progressing on SDG 12.1: Sustainable Consumption/Production?



Scenarios



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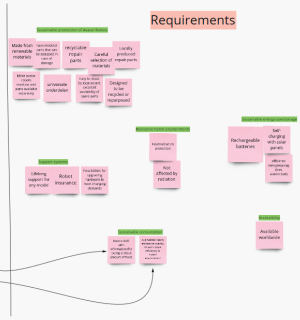


SDG 5.4: Unpaid/Domestic Work

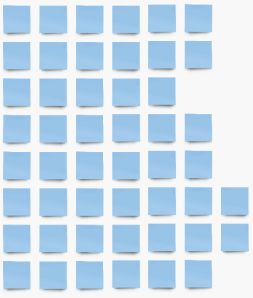
Recognize and value unpaid care and domestic work. Also, shared responsibility within the household and the family should be promoted as nationally appropriate.

Labour force participation, wages and gender gaps may stem from the fact that women spend 2 to 10 times more time on unpaid care work than men. A reduction in time spent has shown to increase female labour participation.

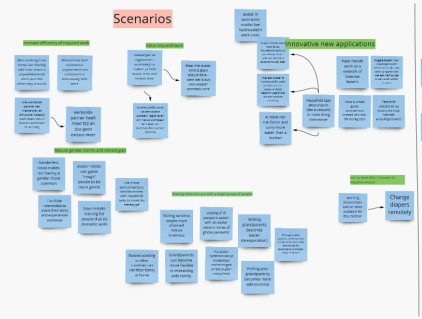
- How can Avatar Robots play a role in time-saving technology and infrastructure? Existing examples are: electrification and improved access to water.
- How can Avatar Robots help tackle gender norms and stereotypes? This is a first step towards shared responsibility for care and housework.

From: G. Ferrant, L.M. Pesando and K. Nowacka, "Unpaid Care Work," *OECD Development Centre*, 2014. (PDF)

Session 5 Question: How can Avatar Robots play a role in progressing on SDG 5.4: Unpaid/Domestic Work?



Scenarios



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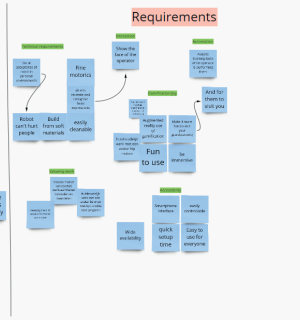


How can Avatar Robots play a role in progressing on SDG 7.3: Energy Efficiency?

Scenarios

Operating efficiency of Avatar Robots

- charging with solar panels
- Avatar robots do not need heating/AirCon
- Use energy-friendly production techniques and materials (no aluminium for example)
- Electric motors designed for energy efficiency
- Regenerative braking
- Energy recovery from movements (like they do with electric cars)

Reduced time and resources spent travelling

- Docenten uit verschillende landen kunnen door middel van avatar robots (gast) colleges geven aan studenten
- Servicing from remote locations
- verplaatsen avatar kan efficienter dan mens (ruimte, klimaat, etc.)
- Geen woon-werk verkeer
- Moving more slowly generally results i less energy loss
- Instead of travelling to a location, use teleoperation to for example meet people.
- Meetings become more interesting
- geen grote kantoorgebouwen meer nodig
- geen verloren tijd bij verplaatsing: efficienter
- Use an avatar instead of traveling to a location
- Geen vakantievluchten
- remote psychologist sessions for people struggling with stress etc.
- Remotely teach people about energy efficiency

Reduced risk of humans being in danger

- avatar robots as a way to replace all builders, to save their backs and other body parts
- Gevaarlijke taken kunnen overgenomen worden door avatars, minder ongelukken?
- Use an avatar as a way to train robots that work in factories etc.
- bevoorrading op moeilijke plekken makkelijker dan voor mens
- using avatar robots to carry heavy items instead of forklifts etc. to still use human dexterity without using humans directly

Spread pollution more evenly across earth

- Spreiding mensen en vervuiling over hele aarde i.p.v. alleen in steden
- werk- en woonplek mensen bij de resources

Requirements

Efficient production of Avatar Robots

- niet afhankelijk van materialen die veel energie kosten om te maken, delven, etc.
- Motivate operator to move more slowly
- Low-energy materials
- Regenerative braking
- produceerbaar met weinig energie
- Electric actuators designed for energy efficiency
- Equivalent experience of being in an other location
- Energy-harvesting equipment
- werken op eigen restenergie

Interaction requirements

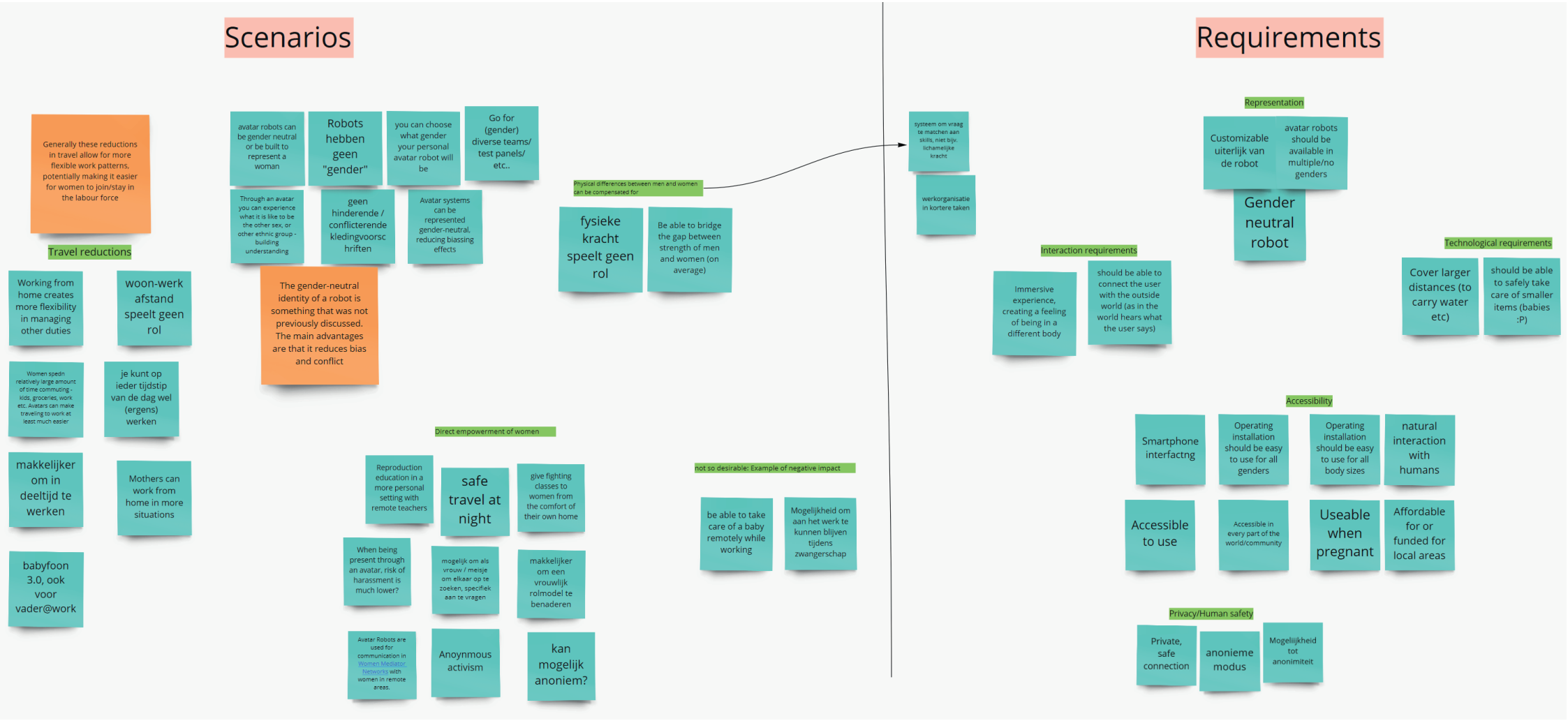
- be able to track human movement correctly
- Transfer motion etc. in real time
- Ability to speak
- Smooth-bi-directional communication through avatar
- multisnsorisch en onderdompelend, tweeweg
- Being able to convey social gestures
- should look similar to a real human
- menselijke vingervlugheid
- should be able to recognise and perform facial expressions
- Spullen aanpakken en gebruiken
- See what the robot can see
- Safe to work with the robot

Technical requirements

- breed inzetbaar in veel locaties (toegankelijk)
- Can withstand accidents
- operationeel over zeer grote afstanden
- opvouwbaar, licht
- be able to deal with different weather situations
- Toolkit to fix its own components
- modulair en recyclebaar. In delen te upgraden
- Curved solar panels
- Avatar robots should be more disposable than humans
- onder extreme omstandigheden/ klimaat operationeel
- Being able to lift heavy things
- the contoller robot should be able to lift more or equal to the amount a human can lift

Miro brainstorm session results

How can Avatar Robots play a role in progressing on SDG 5.5: Women's participation?



How can Avatar Robots play a role in progressing on SDG 13.1: Climate Change Adaptation?

Scenarios

(Heroic) implementation of Avatar Robots to save human lives

- Avatar robots tailored to handling specific natural disasters - firefighting, floods, extreme wind, etc
- quickly provide a "human" shield against the sun
- stackable avatar robots to quickly build a dam
- Reducing the need to go outside in case of hazardous situations - extreme heat or cold for example
- safely traverse dangerous areas
- Take people out of strongly affected areas, required work can be done remotely through avatar systems
- Save physically impaired people from remote areas
- quicker response to environmental disasters
- have avatar robots on standby near areas prone to fire
- Flexibly and quickly get help on site in case of natural disaster - also in remote areas
- Personen met specifieke skills makkelijker en sneller op locatie brengen
- have avatar robots keep watch over people that litter

Preventative action to improve knowledge

- Improve contact with indigenous people to learn from them
- Ability to flexibly visit areas to create awareness and understanding of situations elsewhere
- Get close information about climate disasters that are happening
- Surveillance/prediction research in dangerous areas
- awake more research in the robotics field to increase efficiency

Extend human operating capabilities beyond local area

- als avataroperator kun je leven in een onleefbaar stukje aarde want je hoeft niet naar buiten
- Make remote locations less "remote"
- bouwen en onderhouden windmolenparken en zonnepanelen parken op onmogelijke plaatsen
- je kunt ook onderwater leven en werken omdat je niet naar buiten hoeft
- verspreiden uitstoot (naast verminderen)
- minder olietransport = minder kans op een millieuramp

Requirements

Accessibility

- Widespread access
- Widespread availability

Collaboration

- Interconnectable - one person can embody a group of avatars?
- Multiple people can experience what the robot experiences

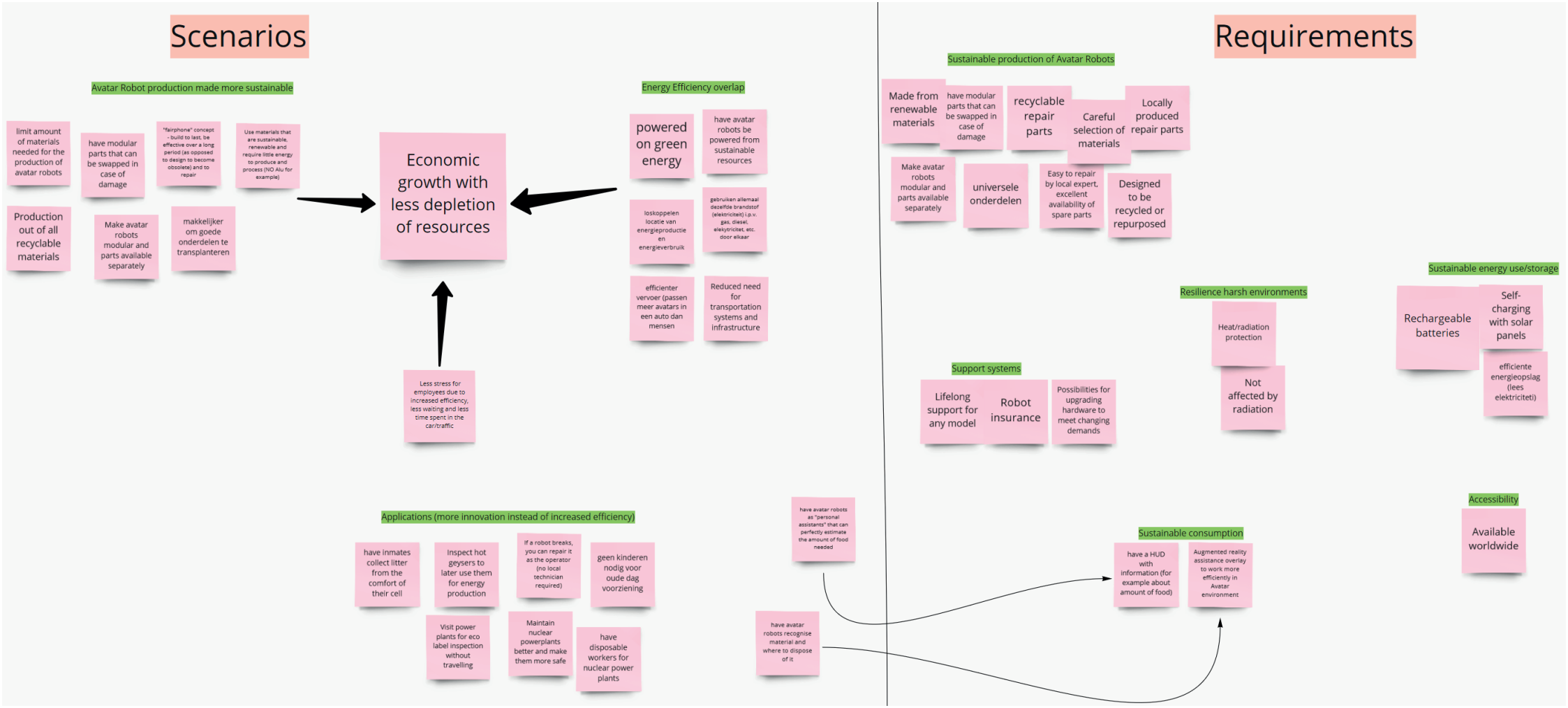
Resilience and weather-proofing (adapted situationally)

- water proof
- fire proof
- be resistant to general wear and tear when stand-by (also from humans)
- moet onder extreme klimatologische omstandigheden kunnen werken
- Needs to respond to specific types of disasters
- Specific systems designed to help in different situations

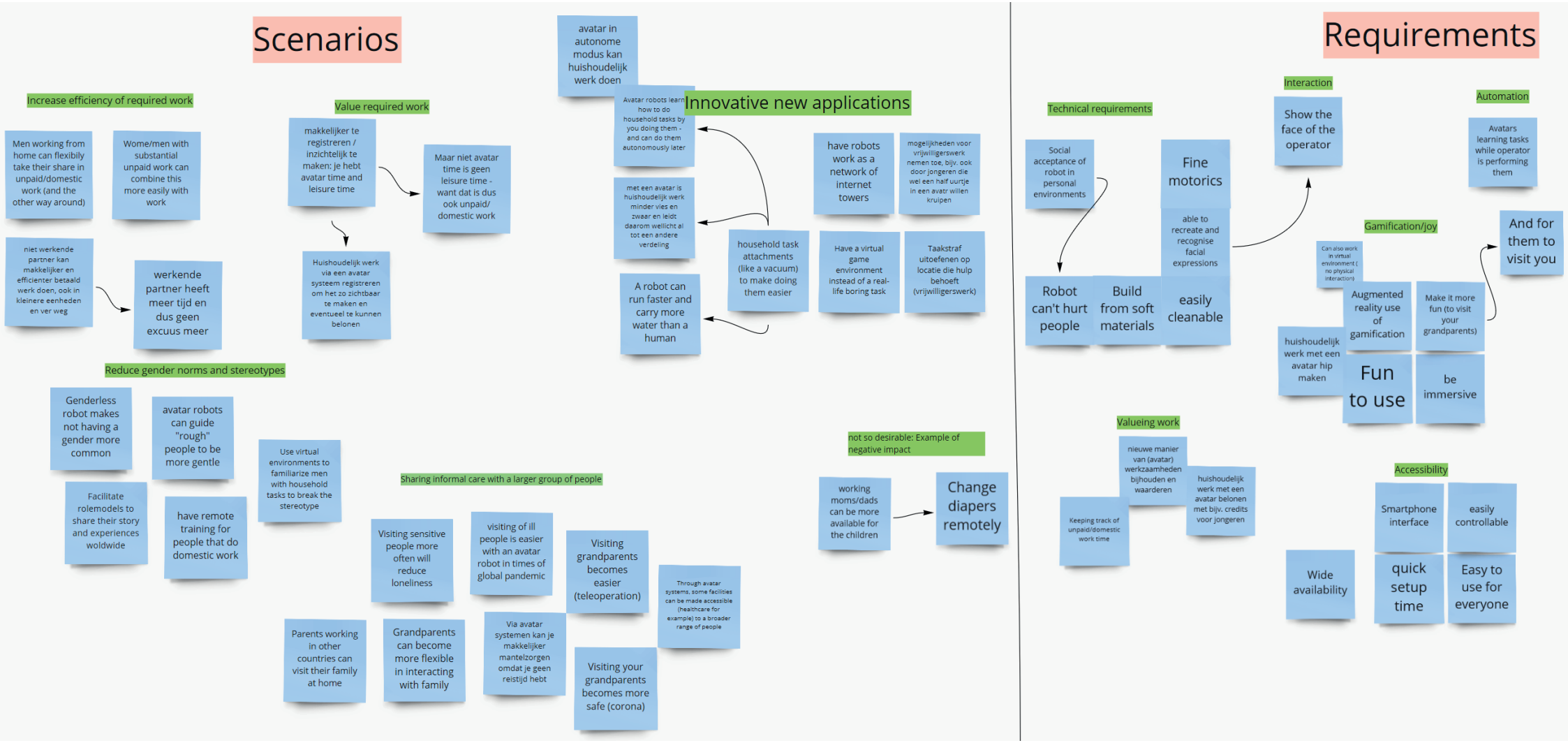
Technical requirements (first time sensors require exceeding human capacities)

- Inhuman eyesight
- Inhuman strenght
- Echo/radar sensors to scan locations
- Heat sensors to find people
- Ability to change shapes
- high level of dexterity to allow for tiny movements

How can Avatar Robots play a role in progressing on SDG 12.1: Sustainable Production/Consumption

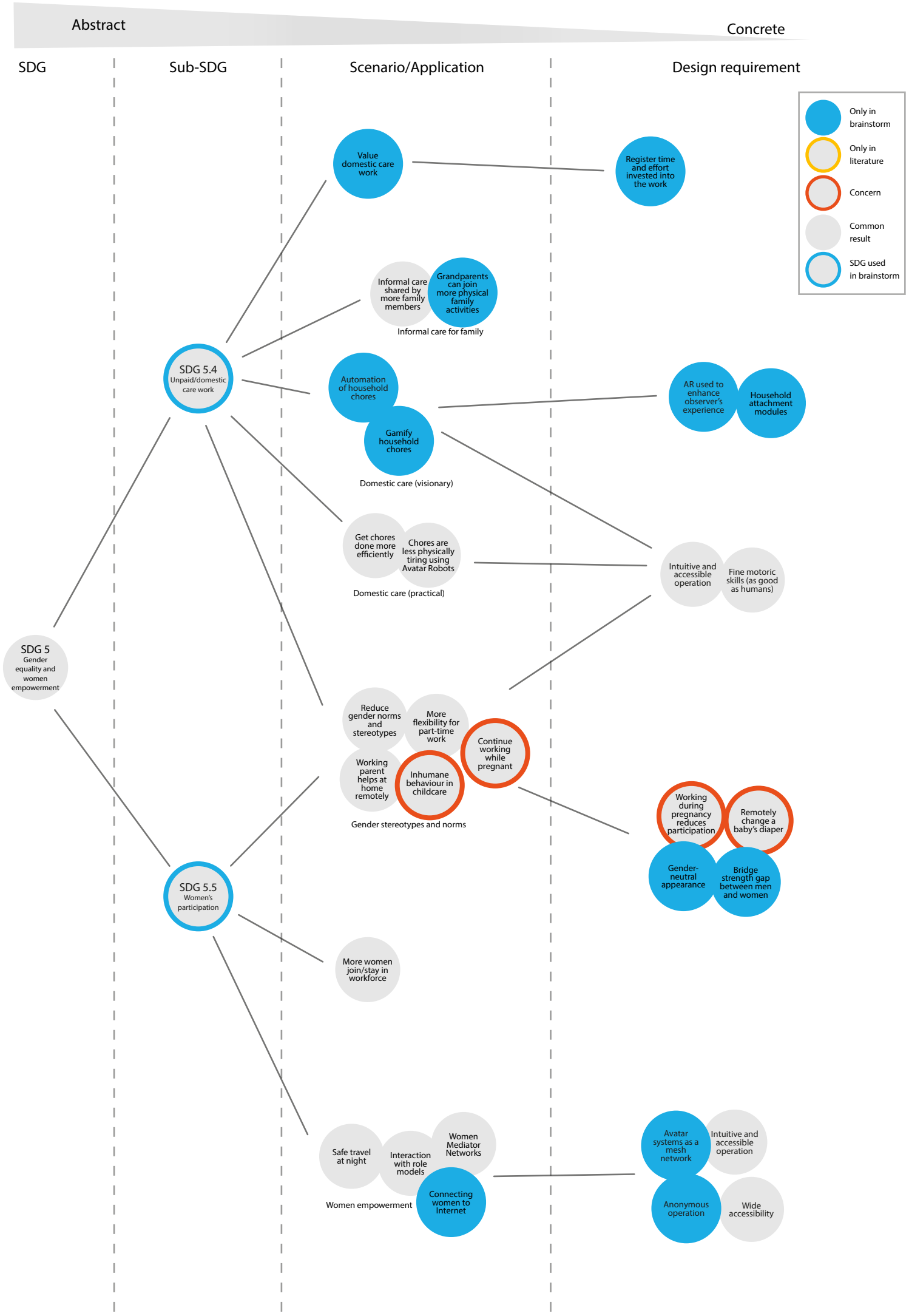


How can Avatar Robots play a role in progressing on SDG 5.4: Women's Participation

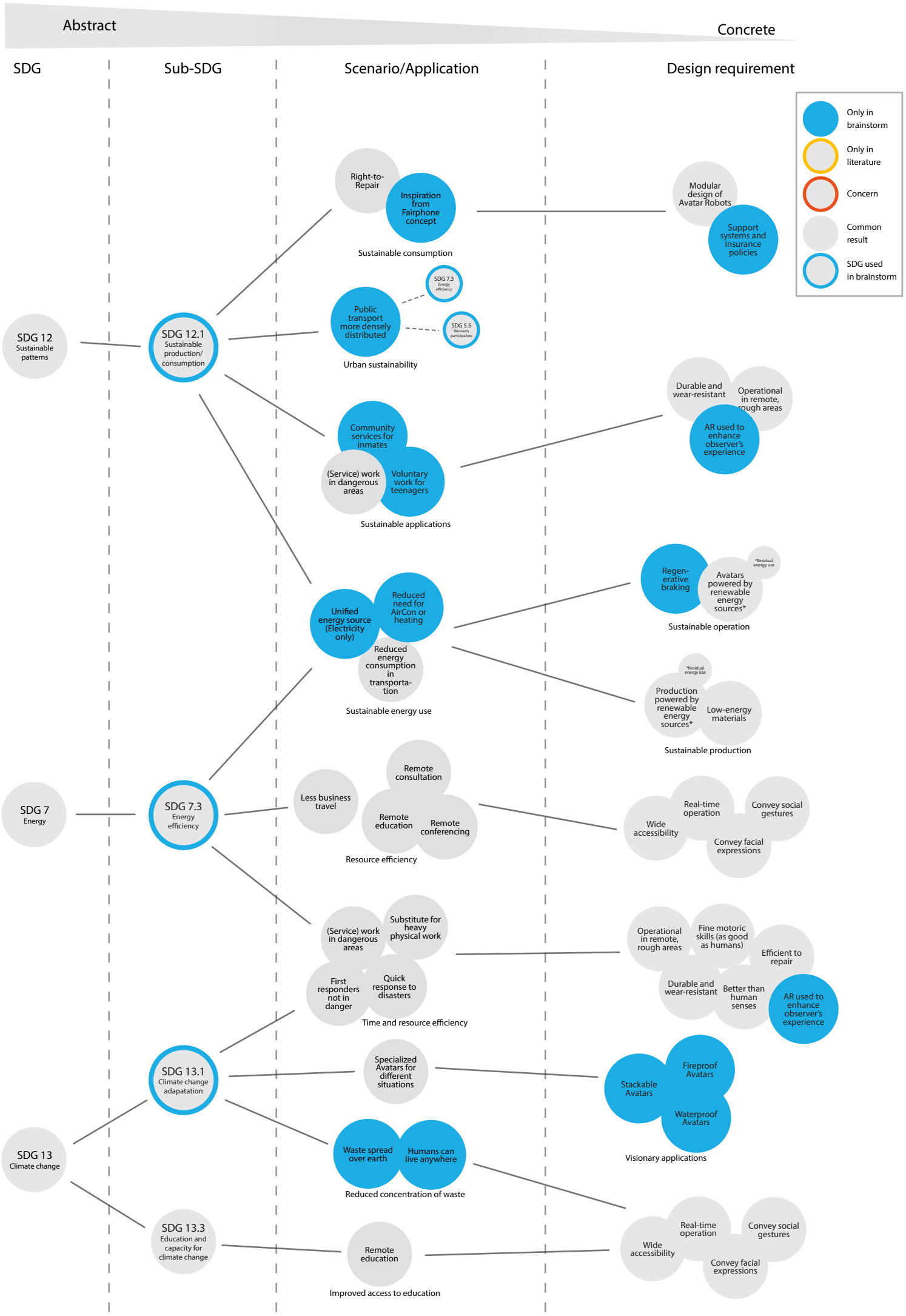


7.3 Combination diagrams of results technology-driven and impact-driven approach

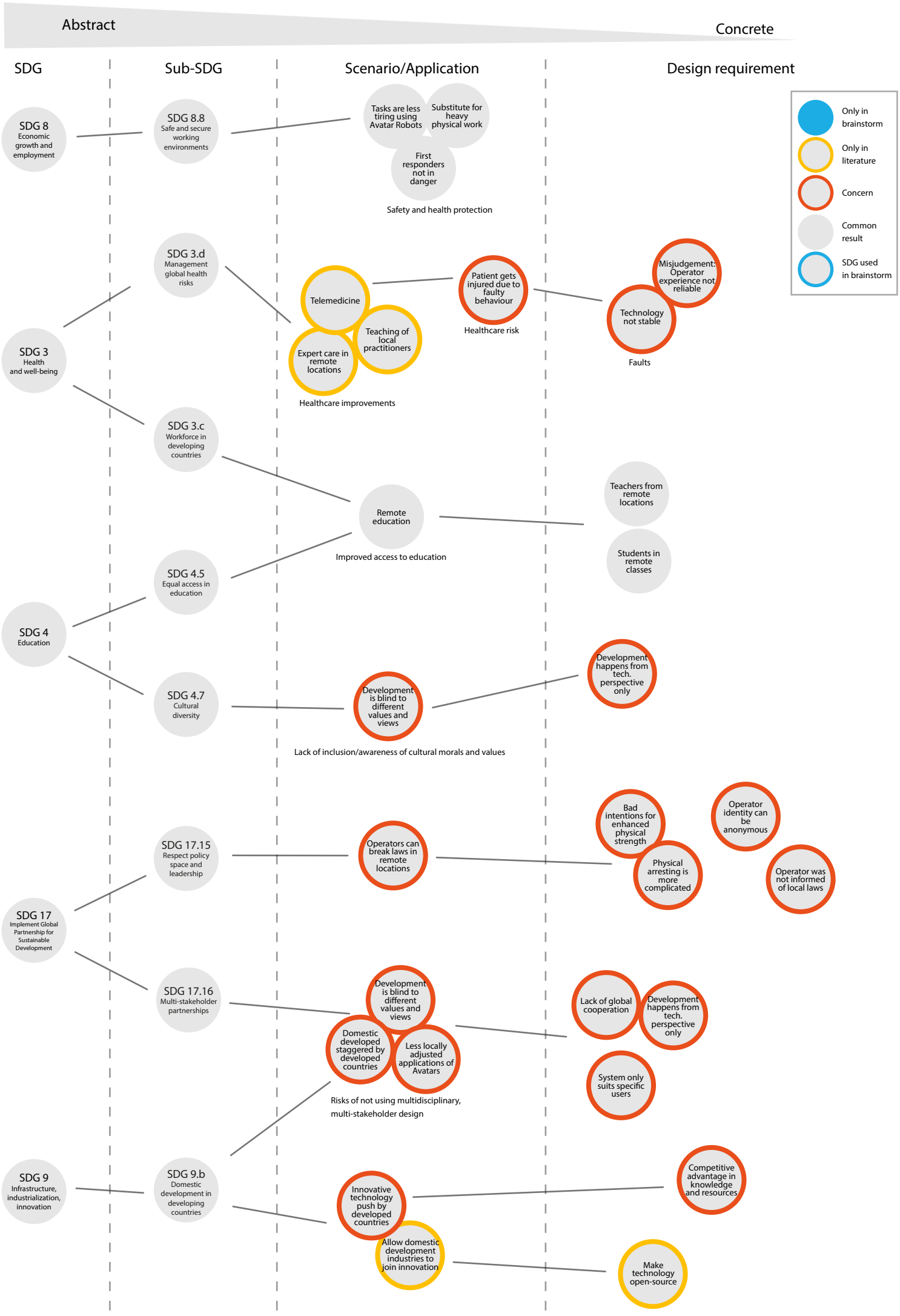
Combined results of technology-driven approach (Chapter 2) and impact-driven approach (Chapter 3-4)



Combined results of technology-driven approach (Chapter 2) and impact-driven approach (Chapter 3-4)



Combined results of technology-driven approach (Chapter 2) and impact-driven approach (Chapter 3-4)



8 REFERENCES

[1] L. Aymerich-Franch, S. Kishore, and M. Slater, “When Your Robot Avatar Misbehaves You Are Likely to Apologize: An Exploration of Guilt During Robot Embodiment,” *Int. J. Soc. Robot.*, vol. 12, no. 1, pp. 217–226, 2020.

[2] D. Snijders, E. Masson, S. Doesborgh, R. Groothuizen, and R. van Est, “Nep echt - Verrijk de wereld met augmented reality,” Den Haag, 2020.

[3] C. R. Evans, M. G. Medina, and A. M. Dwyer, “Telemedicine and telerobotics: from science fiction to reality,” *Updates Surg.*, vol. 70, no. 3, pp. 357–362, 2018.

[4] ARISE, “Avatar Robotics for Immersive Social Experiences - Technical Annex Section 1-3,” 2020.

[5] M. Manyika, James.Chui, S. Lund, J. Bughin, J. Woetzel, P. Batra, and R. Ko, “Jobs lost, jobs gained: Workforce transitions in a time of automation,” *McKinsey Glob. Inst.*, no. December, pp. 1–148, 2017.

[6] F. E. Schneider and D. Wildermuth, “Using robots for firefighters and first responders: Scenario specification and exemplary system description,” *2017 18th Int. Carpathian Control Conf. ICCC 2017*, pp. 216–221, 2017.

[7] R. Luna, B. Cassidy, and J. Franco, *Reducing arc flash risk with the application of protective relays*. 2009.

[8] S. Ryu, “Telemedicine: Opportunities and Developments in Member States: Report on the Second Global Survey on eHealth 2009 (Global Observatory for eHealth Series, Volume 2),” *Healthc. Inform. Res.*, vol. 18, no. 2, pp. 153–155, Jun. 2012.

[9] P. Gambadauro and R. Torrejón, “The ‘tele’ factor in surgery today and tomorrow: implications for surgical training and education,” *Surg. Today*, vol. 43, no. 2, pp. 115–122, 2013.

[10] E. P. Rabinovich, S. Capek, J. S. Kumar, and M. S. Park, “Tele-robotics and artificial-intelligence in stroke care,” *J. Clin. Neurosci.*, vol. 79, pp. 129–132, Sep. 2020.

[11] P. Dario, E. Guglielmelli, B. Allotta, and M. C. Carrozza, “Robotics for medical applications,” *IEEE Robot. Autom. Mag.*, vol. 3, no. 3, pp. 44–56, 1996.

[12] Y. Pan and A. Steed, “A Comparison of Avatar-, Video-, and Robot-Mediated Interaction on Users’ Trust in Expertise ,” *Frontiers in Robotics and AI* , vol. 3. p. 12, 2016.

[13] P. Bremner, O. Celiktutan, and H. Gunes, “Personality perception of robot avatar tele-operators,” *ACM/IEEE Int. Conf. Human-Robot Interact.*, vol. 2016-April, pp. 141–148, 2016.

[14] M. Niemelä, L. van Aerschot, A. Tammela, I. Aaltonen, and H. Lammi, “Towards Ethical Guidelines of Using Telepresence Robots in Residential Care,” *Int. J. Soc. Robot.*, no.

0123456789, 2019.

[15] N. Raison, M. S. Khan, and B. Challacombe, “Telemedicine in Surgery: What are the Opportunities and Hurdles to Realising the Potential?,” *Curr. Urol. Rep.*, vol. 16, no. 7, 2015.

[16] K. Kernaghan, “The rights and wrongs of robotics: Ethics and robots in public organizations,” *Can. Public Adm.*, vol. 57, no. 4, pp. 485–506, Dec. 2014.

[17] M. Slater *et al.*, “The Ethics of Realism in Virtual and Augmented Reality ,” *Frontiers in Virtual Reality* , vol. 1. p. 1, 2020.

[18] E. Helmond, “Van Smart Technology naar Wijze Technologie,” p. 29, 2020.

[19] E. L. Neely, “Augmented reality, augmented ethics: who has the right to augment a particular physical space?,” *Ethics Inf. Technol.*, vol. 21, no. 1, pp. 11–18, 2019.

[20] M. J. Wolf, F. Grodzinsky, and K. Miller, “Augmented Reality All Around Us: Power and Perception at a Crossroads,” *SIGCAS Comput. Soc.*, vol. 45, no. 3, pp. 126–131, 2016.

[21] The World Bank, “Physicians per 1000 people,” 2017. [Online]. Available: https://data.worldbank.org/indicator/SH.MED.PHYS.ZS?end=2017&locations=NL-ZG-IN&start=2011. [Accessed: 05-May-2021].

[22] F. Tanaka and T. Noda, “Telerobotics connecting classrooms between Japan and US: a project overview,” in *19th International Symposium in Robot and Human Interactive Communication*, 2010, pp. 177–178.

[23] X. Yu, “Is environment ‘a city thing’ in China? Rural-urban differences in environmental attitudes,” *J. Environ. Psychol.*, vol. 38, pp. 39–48, 2014.

[24] G. Ferrant, L. M. Pesando, and K. Nowacka, “Unpaid Care Work: The missing link in the analysis of gender gaps in labour outcomes,” *OECD Dev. Cent.*, no. December, p. 12, 2014.

[25] N. Weitz, H. Carlsen, M. Nilsson, and K. Skånberg, “Towards systemic and contextual priority setting for implementing the 2030 Agenda,” *Sustain. Sci.*, vol. 13, no. 2, pp. 531–548, 2018.

[26] EESI, “Energy Efficiency,” 2021. [Online]. Available: https://www.eesi.org/topics/energy-efficiency/description. [Accessed: 11-Jun-2021].

[27] UNFCCC, “What do adaptation to climate change and climate resilience mean? | UNFCCC.” [Online]. Available: https://unfccc.int/topics/adaptation-and-resilience/the-big-picture/what-do-adaptation-to-climate-change-and-climate-resilience-mean. [Accessed: 11-Jun-2021].

[28] UN, “Sustainable consumption and production – United Nations Sustainable Development.” [Online]. Available: https://www.un.org/sustainabledevelopment/sustainable-consumption-production/. [Accessed: 11-Jun-2021].

[29] D. Robertson and M. Ayazi, “How Women Are Using Technology to Advance Gender

Equality and Peace | United States Institute of Peace," 15-Jul-2019. [Online]. Available: https://www.usip.org/publications/2019/07/how-women-are-using-technology-advance-gender-equality-and-peace. [Accessed: 11-Jun-2021].