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DESIGN EDUCATION | AFRIKA | 4TH INDUSTRIAL REVOLUTION

# The influence of the fourth industrial revolution: A multi-discipline approach for design education

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## Abstract

*Klaus Schwab defines the word "revolution" to convey the "abrupt" and "radical" change, which brought about the first, second, third and fourth industrial revolutions. Schwab explains that the fourth industrial revolution (4IR) will transform the way humans communicate, socially connect, function day to day and operate their jobs. The 4IR is not only about technology; its fundamental difference is due to these technologies combining: as a result, the physical, digital and biological spheres overlap.*

*Leading design firms, like that of Neri Oxman, have combined the physical, digital and biological spheres by using computational design, additive manufacturing, material engineering, and synthetic biology. The design philosophy and scientific approach embedded in Oxman's work explore interrelationships among different spheres made possible by specialised in-house teams. These in-house teams form part of the design team to drive creative and innovative solutions. Through this multi-discipline approach, the fusion of the physical, digital and biological spheres is made possible.*

*This paper identifies Oxman's approach as a suitable example that meets the requirements of 4IR as described by Schwab. Through the exploration of the collaborative strategies employed by Oxman's in-house teams, this paper proposes a multi-discipline approach appropriate to design education. This paper will address theoretically how Oxman's multi-discipline team achieves the fusion of the spheres and how this could be incorporated into design education in developing a multi-discipline approach in the curriculum, taking into consideration graduate output associated with the 4IR paradigm.*

*The 4IR and rapidly changing employment skills requirement provide the context of this paper, which is investigated for a richer understanding and how this can impact the future of design education. The 4IR encourages exploring the fusion of the technology spheres, which imparts a collaboration of various disciplines, leading to a continuous multi-discipline domain. While the design industry finds its place within the 4IR, the design education sector's challenge is to produce graduates with creative ideas and relevant skills to function in and contribute to this emerging complex world. Through the exploration of 4IR practices, it is identified that a multi-discipline approach is a differentiating factor for creativity and innovation. Therefore this paper aims to understand how the multi-discipline approach can inform design education to enhance 4IR graduate output expectations in Afrika.*

 

***Keywords***: Collaboration, design education, design industry, fourth industrial revolution (4IR), graduate output requirements, in-house teams, multi-discipline

## Introduction

The 4IR is not only about technology; its fundamental difference is that these technologies combine: as a result, the physical, digital and biological spheres overlap (Schwab, 2016, pp. 1,8). These three spheres are identified in Schwab's (2016, p. 14) book as the technology drivers of the 4IR. The physical sphere refers to tangible technology such as autonomous vehicles, three-dimensional (3D) printing, advanced robotics, and new materials (Schwab, 2016, p. 15). The digital sphere is the internet of things (IoT) that bonds the physical and digital, and it is the association between things, such as products, services and applications, through connected technologies and various platforms that communicate with one another through algorithms, artificial intelligence (AI) and machine learning (ML) (Fox, 2019; Li, Hou & Wu, 2017, p. 627; Schwab, 2016, p. 18). The biological sphere refers to biological exploration, genetic sequencing, synthetic biology and genetic engineering. Examples include clustered regularly interspaced short palindromic repeats (CRISPR) or Material Ecology (Schwab, 2016, p. 21-22; Oxman, 2014, p. 1).

Schwab (2016, p. 10,14-24) indicates that some designers and architects have combined the physical, digital and biological spheres by using computational design, additive manufacturing, material engineering, and synthetic biology. This paper explores Oxman's design approach, demonstrating how the overlapping spheres are integrated into a design project. The paper reflects on work performed by Neri Oxman with a specific focus on the Aguahoja project. Neri Oxman (2019, p. 5) uses the Krebs Cycle of Creativity, which integrates four domains, where disciplines vary, to create innovative solutions that advocate a multi-discipline approach. By combining these domains, the technology megatrends such as computational design, digital fabrication, material science, and synthetic biology are combined, which creates an amalgamation of the spheres in line with the 4IR's fundamental framework.

The collaboration of work and combining multiple disciplines is not new to design education; this form of collaboration is usually multidisciplinarity. A set of disciplines come together to solve a common problem, and once the problem is resolved, the disciplines continue as before (Tolk, 2016, p. 226). The 4IR brings forth another kind of multi-discipline domain where disciplines come together not to solve a problem but to create innovation by blurring the lines of the physical, digital and biological spheres and continue to work together (Schwab, 2016, p. 1,10).

The paper develops an understanding of emerging phenomena in higher education and suggests a multi-discipline approach in this paper to address 4IR graduate output criteria. The exploration of 4IR practices identified that a multi-discipline approach is a differentiating factor for creativity and innovation. Therefore this paper aims to understand how the multi-discipline approach can inform design education to enhance 4IR graduate output expectations in Afrika.

## Methodology

The research methodology used for this paper comprises an integrative literature review. Torraco (2005, p. 357) describes this type of literature review to address new and emerging topics which stimulate new thinking. This paper distinctly employs this approach to generate new knowledge for a topic in a state of exploration and discovery.

 

Torracco (2005, p. 357) explains that using an integrative literature review may lead to an "initial or preliminary conceptualisation of the topic" from which one could extrapolate a new model or framework. Snyder (2019, p. 336) suggests that this approach often requires "creative" data collection methods rather than presenting a review of all published articles. The paper comprises an integrative literature review within the context of the 4IR. Within the 4IR paradigm, Neri Oxman's work is identified and further investigated and explored in an attempt to understand how Oxman developed a multi-discipline approach. Subsequently, the paper extrapolates and suggest a multi-discipline approach for higher design education.

The 4IR and rapidly changing employment skills requirements further contextualise this paper and are investigated to better understand how this can impact design education while exploring a multi-discipline approach. The connection between a 4IR multi-discipline approach and the graduate output requirements is considered essential in postulating strategic drivers for future curriculum or project approaches in design education. In addition, keywords and phrases listed in the Future of Jobs Report 2020 assisted in conducting a critical reflection of South Africa's education's positioning and approach to the 4IR (World Economic Forum, 2020). Klaus Schwab is the founder and Executive Chairman of the World Economic Forum (WEF). The 2020 report, therefore, assisted in guiding our understanding of how a proposed multi-discipline model will positively contribute to how we work, design and think within the 4IR.

## Literature review

*Fourth industrial revolution*

Schwab (2016, p. 3) recognises that several academics and professionals consider the theory of the 4IR to be part of the third industrial revolution. However, three reasons reinforce his view that a fourth and evident revolution is in motion. These three underpinning reasons are velocity, breadth and depth, and systems impact (Schwab, 2016, p. 3).

Schwab (2016, p. 3) explains that the velocity of the 4IR is developing at a rapid rate rather than a linear speed, distinguishing it from previous industrial revolutions, which is the result of a complex interwoven world we live in where new technology keeps on creating further advancements. The breadth and depth of the 4IR is an expansion from the digital revolution or third industrial revolution (Schwab, 2016, p. 3, 7). It merges several technologies forming a unique paradigm shift in individuals, our society, the way businesses run and how economies will function (Schwab, 2016, p. 3). The system's impact of the 4IR is the transformation of whole systems, which influences individuals, societies, industries, companies and countries as a whole (Schwab, 2016, p. 3). Therefore, the velocity, breadth and depth, and systems impact are the underpinning framework supporting the notion that the 4IR is distinct and currently underway.

According to Min Xu, Jeanne M David and Suk Hi Kim (2018, p. 90), this framework brings forth changes in knowledge, power and wealth. With the 4IR bringing changes to individuals, societies, industries, companies, and countries, it is in our best interest to be aware of these changes and take advantage of the knowledge to be learned. Therefore, understanding the framework of the 4IR will help make sense of this paradigm shift and how this knowledge can be used to the advantage of design education.

The 4IR is characterised by the amalgamation of the physical, digital, and biological spheres, which are the technology drivers of this paradigm shift. These technology drivers set the 4IR apart from the previous revolutions (Schwab, 2016, p. 1,8). Schwab (2016, p. 14) further identifies the technology megatrends grouped under the technology drivers. These technology megatrends can be categorised as; physical sphere: autonomous vehicles, 3D printing, advanced robotics and new materials, digital sphere: internet of things (IoT), computational design, connected technologies, various platforms, artificial intelligence (AI) and machine learning (ML), and biological sphere: nanotechnology, biotechnology, synthetic biology and material science (Schwab, 2016, p. 1,10,14-24). New technology is continuously changing and developing; therefore, this list only mentions a few available technologies.

The overlapping of these spheres that happens through the use of the technology megatrends brings forth another type of collaboration, disciplines that are not generally relatable work together and continue to work together but don't blur into each other's domain but share a common body of knowledge. A multi-discipline approach, therefore, emerges through the collaboration and interaction of various project contributors.

*Collaboration and a multi-discipline approach*

According to Bernard Choi and Anita Pak (2006, pp. 351), a multiple discipline approach aims to undertake multifaceted issues, present various viewpoints, give a comprehensive understanding of these issues with complex solutions, and create frameworks for future usage. There are advantages and disadvantages to using a multiple discipline approach (Choi & Pak 2006, pp. 351). Julie Thompson Klein (2010, p. 16) states that a multiple discipline approach can be used differently and has identified three branches; multidisciplinarity, interdisciplinarity and transdisciplinarity.

Through our research, Andreas Tolk emerged as a seminal author on multiple discipline approaches. Tolk (2016, p. 226) offers insight into the differences among the three identified multiple discipline approaches. Multidisciplinarity portrays the "loosest coupling" of disciplines that come together to solve a common problem that contrasts their accepted/known discipline method (Tolk, 2016, p. 226). This approach requires that each discipline resides independently in their domain but adds their experience to the common problem to be solved in an organised system. This results in various disciplinary methods to support one another but not overlapping. After solving the problem, different disciplines continue with their independent domains uninterruptedly. This approach does not pursue a shared "body of knowledge" except overcoming the common problem (Tolk, 2016, p. 226).

Interdisciplinarity generates a "closer linkage" among contributing disciplines (Tolk, 2016, p. 227). With the execution of interdisciplinary projects, the team that represents various disciplines concentrates on overlapping discipline knowledge. As a result, these domains are blended by recognising these overlapping knowledge areas, creating a new common subset that becomes interlinked domains from all participating disciplines. The focus remains to solve common problems but to create long-lasting bridges that connect the disciplines, which supports the new "body of knowledge" (Tolk, 2016, p. 227).

Transdisciplinarity signifies the "strongest coupling" of disciplines. New disciplines are created within the transdisciplinary teams through "transcending, transgressing, and transforming the contributing disciplines and specialities" (Tolk, 2016, p. 227). The knowledge that results from transdisciplinarity is crossbreed along with all the participating disciplines, not only in common terms but integrated within these contributing disciplines. A new hypothesis needs to be made to explain the stemming "body of knowledge" (Tolk, 2016, p. 227). The amalgamation is "systematic and transparent", all disciplines must agree upon the new knowledge and the common use thereof (Tolk, 2016, p. 227).

The multi-discipline approach advocated for in this paper does not fall within multidisciplinarity, interdisciplinarity and transdisciplinarity methods but derives similar aspects. The multi-discipline approach will be reviewed by focusing on Neri Oxman's Krebs Cycle of Creativity and Aguahoja pavilion.

## Neri Oxman

*Krebs cycle of creativity: A multi-modal approach*

Neri Oxman, designer and architect, is the founder and director of Mediated Matter research group at Media Arts and Sciences at Massachusetts Institute of Technology (MIT) (MIT Media Lab 2020b; Oxman, 2015, p. 101). The research group focuses on Nature Inspired Design and Design Inspired Nature. The research area Material Ecology researches the "intersection of computational design, digital fabrication, materials science and synthetic biology, and applies that knowledge to design across disciplines" (MIT Media Lab 2020b). Neri Oxman hypothesises an anti-discipline approach and proposes the Krebs Cycle of Creativity (KCC) as an alternative approach. Oxman's KCC is an adaptation of the Krebs Cycle, the Rich Gold Matrix and John Maeda's Diagram.

Oxman reflects on John Maeda's diagram, as seen in Figure 2, which was based on the Rich Gold Matrix. Maeda's uses the diagram to define areas of creativity and assigns a specific creative approach and outcome to each quadrant. This diagram depicts that 'Science' is for exploration, 'Engineering' is for invention, 'Design' is for communication, and 'Art' is for expression (Oxman 2016a, p. 2). Similarly, the Rich Gold Matrix, as shown in Figure 1, distinctively boundaries the four quadrants: Science, Engineering, Design, and Art. These diagrams suggest that there are distinct modalities of human creativity that reside in the defined boundaries. Oxman reflects that by confining knowledge to any of the four boundaried domains, one will be "a citizen in one" and "a tourist in another" (Oxman 2016a, p. 2). Oxman, therefore, questions, "How we can become constant travellers within a border-free … intellectual Pangea?" (Oxman 2016a, p. 2).

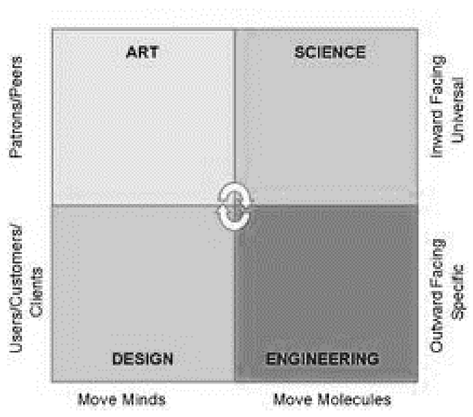


Figure 1: Rich Gold (designer) Rich Gold Matrix (The Rich Gold Matrix 2018)

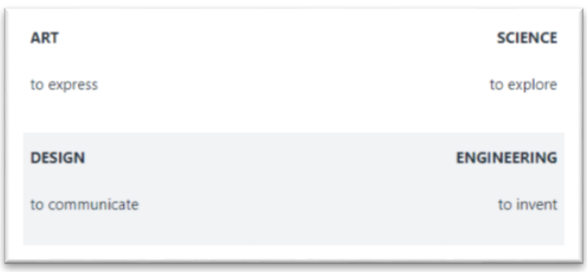


Figure 2: John Maeda (designer) John Maeda Diagram (Maeda, 2017)

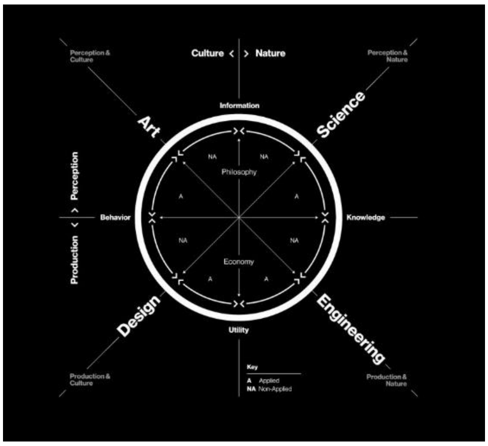


Figure 6: Neri Oxman (designer), Neri Oxman's Krebs Cycle of Creativity (Oxman, 2017)

Oxman refers to biochemistry knowledge focusing on the Krebs Cycle in her quest to offer an alternative approach to ways of being, knowledge generation, investigation and problem-solving. The Krebs Cycle is a chemical process in which energy is harnessed for cellular respiration in the form of Adenosine Triphosphate (ATP). Oxman reflects that ATP can be seen as "a molecular unit of currency for energy transfer" (Oxman 2016a, p. 4). Reflecting on this principle, Oxman proposes that her adaptation, KCC, as seen in Figure 3, is a map that illustrates the perpetuation of creative energy"creative ATP or CreATP" (Oxman 2016a, p. 4).

The KCC positions the four creative approaches as per the Rich Gold Matrix within a circle. However, Oxman (2019, p. 5) suggests that as you travel between and among these quadrants, you "spend currency in the form of intellectual energy", offering an elasticity in exploration not made possible by the Rich Gold Matrix. One can approach, engage, and apply the KCC by observing it as the Clock, the Microscope, the Compass, and the Gyroscope, each offering different opportunities for travelling, exploring and content generation. As a result, discipline residing knowledge in one domain can become the catalyst for discovery in another, which can only be made possible through a multi-discipline approach. Therefore, Oxman (2019, p. 7) argues that "knowledge can no longer be ascribed to, or produced within disciplinary boundaries, but is entirely entangled".

*Aguahoja project*

Through the design of a multi-discipline team and implementing the KCC in her approach, projects like the Aguahoja are conceived. The project Aguahoja focuses on the use of biopolymers that can be used to counter the effects of climate change and pollutions methane-rich manufacturing process (Oxman, 2020). In theory, to replace plastic goods by using bio-polymers instead. The skin-and-shell of the Aguahoja is completely made up of a bio-polymer which is found in nature from shrimp shells (chitin) and fallen leaves (cellulose), that was robotically fabricated through a 3D printing process (Figure 4) and shaped by water (Figure 5) (Oxman, 2020; Oxman, 2017).

 

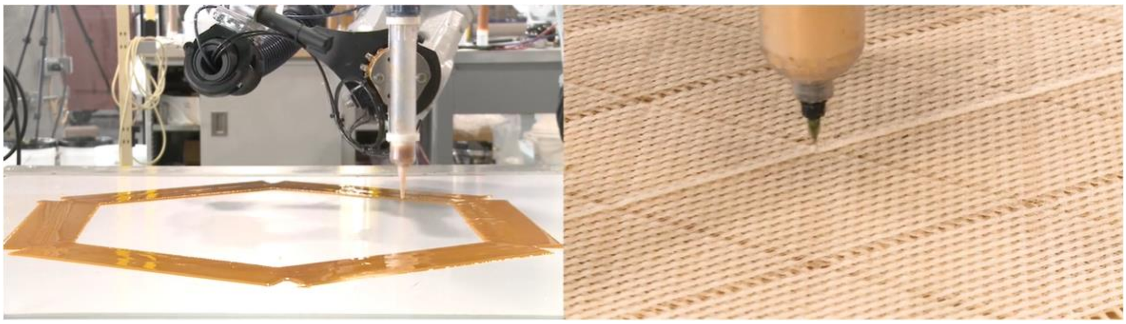

Figure 7: The Mediated Matter group (designer), Aguahoja being 3D printed (MIT Media Lab, 2018)

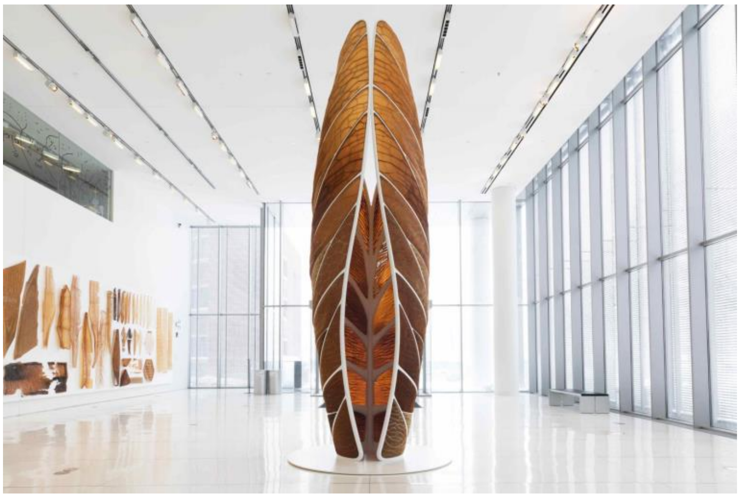

Figure 8: The Mediated Matter group (designer), Aguahoja exhibition (MIT Media Lab, 2018)

The table below has been constructed for the paper to show the disciplines that the various team members represent. This table shows that contributing individuals from the respective science, engineering, art and design domains have specialised knowledge due to their formal training. The Netflix Series *Abstract: The Art of Design*, episode 2 *Neri Oxman: Bio-Architecture* (Sorrentino, Roma & Chowles, 2019) reveals that these individuals do not take up sole residence in their discipline domains. We can observe from this episode that the lab has been constructed to engage collaborative thinking through its interior construction and layout, which encourages a continuous collaborative environment. We further observe that various disciplines gather around a cluster of work desks and critically engage cross-disciplinary thinking in a deep way. One of the team members supports this observation by stating that they "have to do just know about everything" (Sorrentino, Roma & Chowles, 2019). Knowledge no longer resides in a single discipline but is shared and acquired to generate new knowledge for undefined problems.

Table 1 Research team, discipline and department

| Research team member | Discipline (degrees) | Department |
|---|---|---|
| Jorge Duro-Royo | Structural Design and Construction. | Department of Architecture and Urban Planning |
| Laia Mogas-Soldevilla | Visual Arts, Architect, Advanced Design and Digital Architecture. | Department of Architecture and Urban Planning |

 

| | | |
|---|---|---|
| Joshua Van Zak | Chemistry and Systems Biology | Past member of Tangible Media |
| Yen-Ju (Tim) Tai | Architect | Past member of Mediated Matter Group |
| Andrea Ling | Designer and Architect | Past member of Mediated Matter Group |
| Christoph Bader | Information Design and Computer Science | Mediated Matter Group |
| Nic Lee (Hogan) | Biomedical Engineering, Neuroscience, Media Arts and Sciences | Mediated Matter Group |
| Barrak Darweesh | Architect and Designer | Past member of Mediated Matter Group |
| James C. Weaver | Aquatic Biology, Marine Science, Molecular Biology, Chemical Engineering, Physics, and Earth Sciences. | Mediated Matter Group |
| Nitzan Zilberman | Architect | Department of Architecture and Urban Planning |
| Neri Oxman | Architect, Designer, Design Computation and Medical Science | Media Arts and Sciences, and Mediated Matter Group. |

Source: (table compiled by authors) (Ling, 2021; Linkedin, 2021; Duro-Royo, Mogas-Soldevila & Oxman, 2015; Mediated Matter, 2020a; Mediated Matter, 2020b; Mediated Matter, 2020c; Mediated Matter, 2020d; MIT Architecture, 2019; MIT Media Lab, 2020a; MIT Media Lab, 2020c; Mogas-Soldevila, et al., 2015).

## Findings: Design education in an Afrikan context

This section discusses findings identified through the literature review that show the impact of 4IR on design education. A gap in the education sector's approach in the 4IR and an opportunity for the education sector emerges within our discussion. Therefore, in response, the discussion advocates the value of incorporating a multi-discipline approach in a design education curriculum.

### *Graduate output requirements within 4IR*

The 4IR paradigm connection to the graduate output requirements is considered essential in presenting the future graduate output requirements for design education. While the design discipline finds its place within the 4IR, the design education sector's challenge is to produce graduates with creative ideas and skills relevant to this emerging complex world. The 2020 WEF's Future of Jobs report takes into consideration the impact of the "two twin events" (World Economic Forum, 2020, p. 12), being the arrival of the 4IR and the sudden impact of COVID-19 recession across the world.

The WEF data gathered for South African industries identify a list of emerging high demand skills. Among the skills listed, the following activities resonate well with design education activities: analytical thinking and innovation; critical thinking and analysis; complex problem solving; creativity, originality and initiative; and reasoning, problem-solving, and ideation (World Economic Forum, 2020, p. 105). The top three essential emerging skills in high demand in South Africa are creativity, originality and initiative; active learning and learning strategies; and technology design and programming (World Economic Forum, 2020, p. 105).

The emerging high demand skills identified in the report show the inherent strengths of the design curriculum when preparing graduates to take part in the 4IR world of work. The design curriculum focus is, therefore, well positioned to strengthen these emerging skills as strategic drivers in developing an appropriate 4IR approach. The responsibility of design educators is to incorporate these skills within the emerging context of the 4IR.

*Actively embrace 4IR in the education system*

Rodny-Gumede (2019) reports that diversity, flexibility, and creativity do not reflect South Africa's economy, job market, education system, or societal organisation due to its political past. This identifies the gap in the education sector's approach in the 4IR and an opportunity for the education sector. Current literature suggests that by actively embracing the 4IR, the education system is well-positioned to cultivate innovation and talent (Rodny-Gumede, 2019; Xing & Marwala, 2017, p. 13; Kayembe & Nel, 2019, p. 92).

The impact of COVID-19 and lockdown had a sudden impact on our design of teaching and learning strategies. The incorporation of technology-assisted greatly in the presentation of online classes and distance learning. The incorporation of technology, however, represent one sphere of the 4IR. The design education should actively embrace a more comprehensive and full spectrum of 4IR requirements to prepare graduates for a job environment that requires flexibility, creativity and innovation.

According to John Butler-Adam (2018, p. 1), future jobs have not been envisaged yet with the ever-developing technology, and highly skilled professionals will grow into their positions or be moulded for the needed job through the developing technology they work alongside. Therefore, students would need to learn how to adapt and be flexible in the working industry as their original profession may develop as the technology they use develops.

*Include opportunities for multi-discipline collaboration*

The KCC and the multi-discipline approach included in Neri Oxman's work provides insight into a revised design approach that stretches beyond design discipline boundaries. The approach further illustrates how the 4IR technology megatrends and overlapping physical, digital and biological spheres, identified by Schwab, is integrated into a design process. Design education can extrapolate valuable lessons from work performed by Neri Oxman, which offers guidance in providing a deeper understanding and richer application of 4IR influences in the design education curriculum and the students' execution of the design process.

Students from various disciplines should be encouraged to use creative and innovative thinking skills to explore problems through overlapping the various spheres. Design students should be guided through collaborative thinking processes and understand that multi-discipline work will expand knowledge and problem-solving. Creative and innovative thinking skills should take place beyond the boundaries of the discipline activities. This approach will require students to become travellers and explorers of knowledge in the fields of science, engineering, art and design. The design team should include a range of participants to inform and represent the complexities associated with our modern world and immediate vernacular context.

Integrating a multi-discipline process in design education will require design educators to include collaborative projects that will bring together a far wider group of participants. The vernacular (Afrika) context cannot be ignored and should be included to address social, economic and environmental factors in the design thinking process. This will allow Engineers, Scientists, Designers and Artists to investigate and explore problems, with the opportunity to generate knowledge. The aim is not to focus on a problem space but rather a solutions space where design students are curious and investigative. Students will become entangled with complex problems and explore solutions beyond disciplinary boundaries.

## Conclusion

The paper identifies that the 4IR is not only about the introduction of technology and advancement of technology. As identified by Schwab (2016, p. 1,8), the fundamental difference is the overlapping of physical, digital and biological spheres. The paper explores the work of Neri Oxman and her design team's work to understand how she developed her multi-discipline approach, as expressed in the KCC and included in the execution of her design projects. Oxman's KCC and the emphasis on a multi-discipline approach presents insight into how the design education could understand the thinking and value of a multi-discipline team that contribute to developing design innovations.

The study identified that the design education sector naturally aligns itself with the high-demand emerging skills associated with rapidly changing 4IR. Emerging skills that will require creativity, innovation, and complex thinking are already embedded in design education curricula. The design education sector should understand how to cultivate these high demand skills, actively embrace participation in the 4IR paradigm, and consider introducing alternative teaching and learning strategies to prepare students for the complex 4IR work environment. Design education is consequently well-positioned to address this gap currently identified in this paper. By engaging alternative teaching and learning strategies, such as the multi-discipline approach, the sector can enable students to travel, explore, test, and investigate design within a world associated with complexity, rapid change, and the continuous introduction of new technologies.

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