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SPECIAL FEATURE: TECHNICAL REPORT

Synergies and Trade-offs between Sustainable Development Goals and Targets

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The role of universities in SDGs solution co-creation and implementation: a human-centered design and shared-action learning process

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Abstract

Successful implementation of solutions to reach the UN Sustainable Development Goals (SDGs) depends on harnessing synergistic interactions among SDGs and effective engagement among a diverse group of societal stakeholders. This paper presents a framework and case study for a design and engagement process in which the university takes the lead in the co-creation of SDG solutions. The model supports university-led efforts by leveraging three elements: (i) inherent synergies across SDGs, (ii) modes of solution identification, design, and implementation, and (iii) modes of stakeholder involvement and interactions. Using an integration of human-centered design (HCD) and shared-action learning (SAL), we document a case led by a large, public, research-oriented university on how different stakeholders participated in the co-creation process to find solutions. Based on the experience of about 50 students over 4 years in support of SDG implementation in Indonesia, the initiative leveraged synergies within SDG 1, 2, and 5 (related to increasing income-generating power for women and indigenous people) and SDG 7 (use of solar energy for fish preservation and crop processing). Throughout the process, interactions with stakeholders took place during design workshop courses, community consultations, mentoring and internships programs, partnering with companies and local universities and government, site visits, and immersions in local communities. The HCD-SAL model established a system for monitoring impacts across all stakeholders, particularly how the projects helped increase communities' economic well-being. This model provides guidance for universities to develop genuine stakeholder engagement and support for finding and continuously improving SDG solutions.

Keywords Solution co-creation · University-led process · Continuous improvement · Development competencies · Local community

Introduction

The UN Sustainable Development Goals (SDGs) have been considered as the transformative pathways that will lead to a more equitable global society and sustainable planet. However, challenges abound. One key challenge is how to get government, business, non-governmental organizations, civil society, and academia involved to work together for

impactful implementation of SDG initiatives (Lavery 2018). Under the SDG agenda, businesses, governments, and civil society actors are equally called upon to pursue a more sustainable path forward. In this context, universities can play a crucial role in bringing together a diverse group of societal stakeholders to take action and make an impact (Sedlacek 2013; Leal Filho et al. 2019).

In recent years, university-led community engagement initiatives are gaining momentum, driven by shifting perspectives, as well as demand by students for greater involvement with real-world actors and problems. First, there has been a shift of the role of higher education institutions (HEIs) from knowledge producer to co-creator of solutions (Trencher et al. 2017). HEIs are becoming hubs for innovation, creativity, and collaboration towards addressing

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the world's development challenges, as well as engines of societal transformation (Hutchins, et al. 2013; Purcell et al. 2019). With many well-established comprehensive undergraduate and graduate academic programs in sustainability, students have expressed not only enthusiasm but also the demand for real-world experience and impacts. Students have been key agents of change in sustainability science and multi-stakeholder partnerships (Daneri et al. 2015).

Second, there have been significant shifts in the role of the private sector in the development of SDG solutions (Scheyvens et al. 2016). 'A new paradigm in development thinking is recognizing the centrality of private enterprise in pursuit of the development agenda—and vice versa.' (UN 2014, p. 3). In particular, transnational corporations (TNCs) have been facing growing expectations that they become involved with sustainable development (Schönherr et al. 2017). The private sector has important resources, including innovation, responsiveness, efficiency, and specific skills. Their integration of sustainability related practices, however, remains underdeveloped (Scheyvens et al. 2016). The UN's SDG agenda can be used as a reference framework that may help TNCs better link core business operations and corporate social responsibility (CSR) with sustainable development.

Third, there has been a readjustment of local government and NGOs to adopt the SDG framework and be a key implementation partner in the achievement of SDGs. One important issue has been how to evaluate the local impacts of the SDGs efforts and ensure that local interests are prioritized and solutions successfully implemented (Reddy 2016). At the same time, NGOs are mobilizing around SDGs to ensure that they are implemented at a local and national level. As to the latter, NGOs can assume four roles: holding governments to account, communicating the SDGs to a broad audience, implementing projects, and holding the private sector accountable (Hege and Demailly 2018). Lastly, the role of community members has moved from the periphery, where they were treated as passive consumers of knowledge and interventions, to a central role in which they have a voice in project development.

Furthermore, there has been a greater recognition of and push toward harnessing synergies among SDGs to improve SDG attainment, with significant savings of precious resources (Kroll et al 2019; Pedercini et al. 2019). In general, there are more synergistic than trade-off relationships (Pradhan et al. 2017; Nilsson et al. 2018). SDG1 (No poverty) was found to have the most synergistic relationships with other goals, whereas SDG12 (Sustainable consumption and production) has the most trade-offs (e.g., food production can negatively affect land use and generates carbon emissions) (Kroll et al 2019).

Universities can benefits from these insights to develop projects aimed at achieving SDGs at the community level. These include enhanced collaboration between academics and practitioners, joint problem definition involving relevant stakeholders, and the guidance of students to participate successfully in collaborative, real-world projects (Brundiers and Wiek 2011). Given the identified impetus and challenges, the paper addresses the following questions:

> How can we better integrate the academic institution with broader societal elements in implementing SDGs initiatives? How can university-led SDGs initiatives harness inherent synergies among SDGs at a local community level? What are the conditions necessary for establishing meaningful and impactful stakeholders' engagement?

To get the stakeholders more effectively engaged, this paper integrates a human-centered design (HCD) and a shared-action learning (SAL) approach. HCD puts people and communities at the center of the design process, rather than tackling design challenges from internal/organizational or technical frames (Young 2010). SAL provides stakeholders engaged in sustainable community development projects with a common set of ideas and vocabulary from which to work and produce focused plans, actionable insight, and tangible results for partners and communities (Jiusto et al. 2013). In this work, led by a public university in the U.S., an integrated HCD-SAL framework and model has been developed and implemented in local communities on the Indonesian islands of Lombok and Papua over 4 years. University-led SDG projects aim to improve the livelihood of smallholder farmers and fishermen by leveraging synergies within SDG 1 and 2 (related to increasing income-generating power to reduce poverty), SDG 5 (empowering women cooperatives through access to economic resources), and SDG 7 (using a solar-powered ice maker for fish preservation).

The remainder of the paper is structured as follows. We first build and describe the building blocks of the HCD and SAL framework. Next, we describe the case study method, covering background of the study areas and communities, stakeholders involved, and data collection. We present the application of the model's key sub-processes, the evaluation of impacts, and reflect on lessons learned and general applicability. The paper concludes with a discussion on the study's broader implications and suggestions for future work.

Building blocks to the framework

University-led community development in the literature

Universities are uniquely positioned to play a leading role and serve as the engine of transformational sustainability toward delivering solutions to the SDGs. They are embedded

within communities whose diverse histories, geographies, and members offer infinite opportunities for partnership, research, and actions toward improving the well-being of people and the planet. Universities are a "living lab" (Purcell et al. 2019), participating in action oriented research (Trott et al. 2018) and sustainability research education (Brundiers and Wiek 2011), with deep connections to a wide stakeholder community.

Co-creation of solutions

To maximize universities' potential, their role must change from that of a producer to co-creator of knowledge and solutions. The concept of co-creation of solutions is of particular importance for supporting sustainable development initiatives (Lang et al. 2012; Polk 2015). In a co-creation process, users/customers are positioned as experts in their own rights (Sanders and Simons 2009). Co-creation has been proposed to better understand and facilitate the collaborative process among stakeholders (Trencher et al. 2017), which entails that the university "collaborates with diverse social actors to create societal transformations in the goal of materializing sustainable development in a specific location, region or societal sub-sector" (Trencher et al. 2014, p. 152).

Main elements for co-creation and implementation of SDGs solutions

This work pursues a holistic process that accounts for interactions among SDGs and engagement among a diverse group of societal stakeholders, which involves a joint undertaking in all stages of a project, from conception to implementation (Simon et al. 2018). First, it is essential that an SDG project initiative harness synergistic SDGs interactions to maximize co-benefits (i.e., the aggregate impact is greater than the sum of the individual impacts) (Pedercini et al. 2019).

Second, the framework provides practical guidance during the process with an emphasis on a solution design mindset and skills (Wiek et al. 2011, 2015). The focus is on synthesis to create an effective solution by drawing together different perspectives on problems and their contexts, technologies, human needs, and empathy for users and stakeholders. Design thinking prescribes a process in which multidisciplinary teams take a user-oriented approach to arrive at relevant solutions to complex or 'wicked' problems (Buhl et al. 2019).

Third, the process of designing SDG solutions and their implementation involves diverse and inclusive types of actors. Engagements with stakeholders are intensive and immersive. Each stakeholder type can assume a unique role: universities (drivers of solution co-creation innovations), private companies (funding, internship positions), NGOs (administration of

solutions), and local government (access permits). In terms of collective governance, one way to build transparent and sustainable relationships is to institutionalize universities' partnerships with government and community organizations (Percy et al. 2006; Holland 2009). Such an institutionalization may manifest within universities' strategic planning and through an establishment of a partnerships structure that includes aspects such as governance, staffing, and leadership, as well as an evaluation and reporting process.

Last, given the uncertainties regarding socioeconomic dynamics at local, national, and global levels, implemented SDG solutions can change. Therefore, a mechanism that facilitates continuous improvement based on regular performance monitoring and evaluation needs to be in place (Bhuiyan and Baghel 2005). Sustaining this process entails a university's long-term commitment to communities beyond short-term academic calendar cycles.

## Human-centered design (HCD) and shared-action learning (SAL) framework

A combined HCD and SAL framework is developed by leveraging and integrating three elements: (i) inherent synergies across SDGs (ii) modes of solution identification, design, and implementation, and (iii) modes of stakeholder involvement and interactions (Fig. 1). The model is operationalized through shared learning experiences and some core competencies, including a design mindset, problem solving, conflict management, immersion, and empathy (Wiek et al. 2015).

In this framework, the roles of lead and local universities are different, because there are cultural gaps (e.g., language and traditions) between the lead university and targeted local communities, which poses a significant challenge for communication and solution implementation. The lead university's main role is first to develop a vision of community development engagement relative to the SDGs. It then needs to build the infrastructure necessary to involve students and faculties (e.g., courses, travel support, seed funding) and engage with stakeholders (e.g., internships and community immersion programs). This vision is shared with the involved local universities, which have an advantage of being culturally better connected with the local stakeholders and having easier access to local resources. Students and faculty at the local university serve to bridge cultural gaps, provide logistical support, and share local knowledge and technical facilities.

Harnessing synergies among SDG targets

In the first facet (core layer), patterns of SDG interactions can be revealed through a network analysis (Le Blanc 2015). Each SDG can be considered as a node and the linkage

Fig. 1 A framework for developing university-led initiatives for the co-creation and implementation of SDG solutions
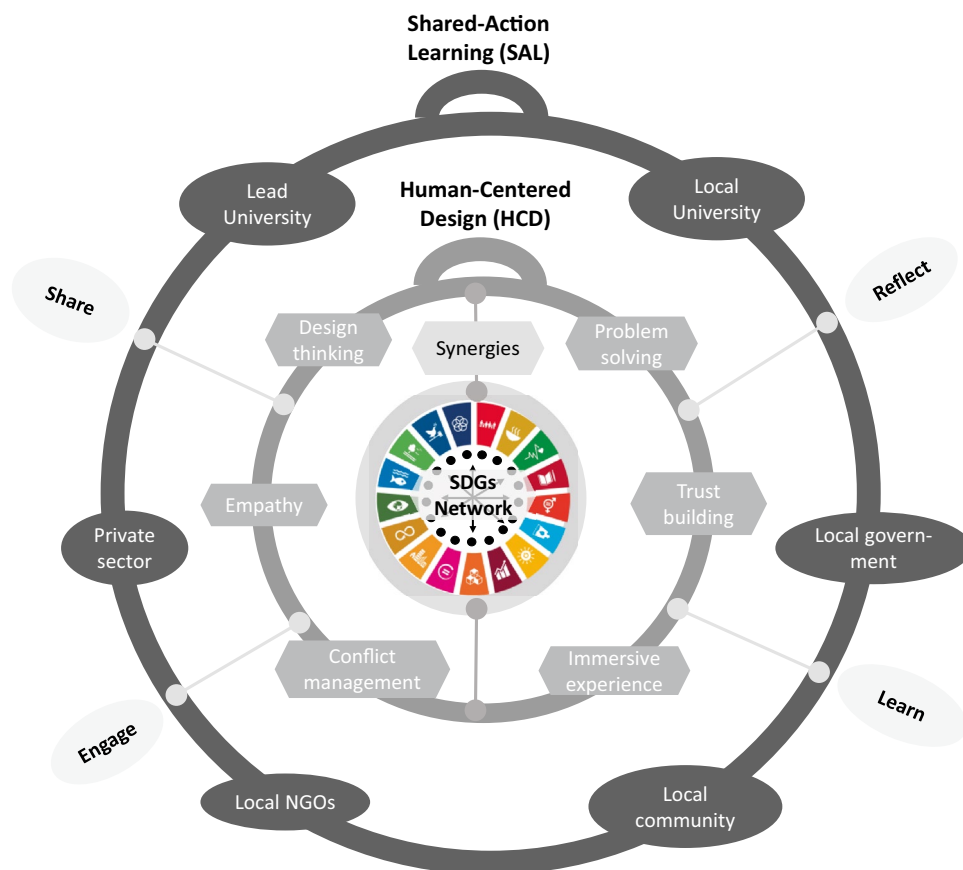
represents a connection between two SDGs, either as a synergy (positive correlation / co-benefits) or a trade-off (negative interactions: the achievement of one at the expense of the other) among SDGs. The main challenge is that data at a local level that are needed to establish meaningful quantitative patterns may be scarce, intermittent, and/or unsuitable for the purpose of the SDG project.

One approach is to make use of local knowledge by consulting with the local communities, NGOs, and government to identify a focused area of SDG challenge. To illustrate, as a starting point, our stakeholders' consultation, initiated by the lead university, identified one major development challenge, which was to improve the community's income to reduce the poverty level (SDG 1 and 2). The scope of synergies is then explored depending on local conditions. A geographical location in which sunlight is abundant, for example, points to the potential use of solar energy as a solution (SDG 7), which in turn can improve health conditions due to less local air pollution (SDG 3) caused by electricity generated from fossil fuels. Furthermore, the availability of human capital in the form of women NGOs could reduce gender inequality by giving them access to production resources (SDG 5). When the additional income is used to support child education, the level of completion of primary and secondary education could increase (SDG 4).

The modes of solution identification, design, and implementation processes

The second facet (middle layer) involves an HCD process, that is, creative problem solving that prioritizes direct engagement with various stakeholders to obtain insights that may be critical to designing solutions that are both novel and useful to the target communities (Macdonald and Putzer 2019). It brings the needs of people and communities to the center of the solution design process by leveraging empathy, collective idea generation, rapid prototyping, and continuous testing to tackle complex development challenges (Young 2010). Adoption of the HCD process involves a cycle of four design activities: (a) problem/opportunity framing, (b) solution development, (c) testing, and (d) critical reflection (Maher et al. 2018).

The modes of stakeholder involvement and interactions

The third facet (outer layer) involves SAL processes in which different stakeholders participate in various stages of solution co-creation and implementation. Such a process is facilitated with a common set of ideas and vocabulary from which to work and produce focused plans, actionable insight, and

tangible results for partners and communities (Jiusto et al. 2013). With a focus on sharing, learning, and reflection, each SAL experience is unique as it is defined by the social, cultural, and ecological context within which the project is situated (Jiusto et al. 2013). University students, in particular, can gain valuable experience and knowledge by interacting with community stakeholders and organizations. Throughout the entire process, interactions take place in design courses, community consultations, internships, student mentoring programs, site visits, and diverse immersive experiences.

Core competencies and shared-learning experience

Within university sustainability programs and for practitioners in the international development arena, some core competencies have been identified (Wiek et al. 2011; Brière et al. 2015; Kock and Weeks 2015). They can manifest in problem solving, mediating and resolving conflicts, and empathy, compassion, and solidarity. Effective application of the HCD-SAL framework depends on several key competencies, illustrated in the second layer of Fig. 1 and described in Table 1.

From the framework to a working model

A working model that can be operationalized by universities consists of eight major sub-processes that take place across three settings: academic, internship, and community (Fig. 2). They range from loose coordination in the academic setting, to one-on-one interaction in the internship setting, to tight coordination in the community setting. What ties these together are shared learning and continuous feedback.

Two sub-processes take place within the academic environment: internal university activities and support in which students and faculties develop sustainable solution ideas (1) in consultation with stakeholders (2). Students are placed in an internship with the stakeholders (3) to expose them to real-world experience and collect relevant data. In the community setting, leading and partner universities test and adjust the solution prototype (4) before implementing it in the community (5). Once completed, the operations and maintenance of the implemented solution are handed over to the local stakeholders to manage (6). Impact assessment is conducted throughout the process (7). The three settings are linked together through shared learning and continuous improvement (8).

Methods: case study

Study areas and communities

Our 4-year study focused on efforts to address development challenges in Indonesia. In 2020, it ranked 97 out of 165 countries in the SDG index (i.e., an indicator of overall achievement of SDGs) with a score of 66.3 out of 100 (Sachs et al. 2021). We focus on two regions: North Lombok and Mimika in the West Nusa Tenggara and Papua provinces, respectively. They are the least developed provinces according to the human development index (HDI), which assesses literacy, life expectancy, education, and income (World Food Program 2013).

In North Lombok, over 80% of the population relies on subsistence agriculture and about 30% are poor (KLU 2017). The first targeted community is the Hamlet of Karang Kerakas, which is a fishing community where most of the male population works as fishermen and the women as fish sellers. Second is the Hamlet of Gumantar, which depends on the farming of cocoa and coffee. In Mimika, two local indigenous communities are targeted. First is the hamlet of Otakwa, in a coastal area populated by the indigenous Kamoro, who depend on fisheries and cocoa farming. It is situated within the Lorentz national park, which, because of its rich and unique biodiversity, was declared a World Heritage Site by UNESCO. Second is the indigenous Amungme people living in the mountainous region of Papua. They are largely subsistence coffee farmers. Both indigenous communities in Mimika have been affected by mining activities in the region.

Development challenges and SDGs synergies

The main developmental challenge was poverty eradication for small-scale food producers through increasing their household income. A focus group discussion conducted with the local university partner and the government of North Lombok identified the need for preservation of fish to guard against fluctuations in catches. A costly preservation of fish using fossil fuels in Mimika was identified during a separate meeting with a mining company and a local NGO. Fisheries have been one top priority for the mining company as part of their economic development initiative for coastal areas. For communities that depend on farming, a major issue was the low quality of the coffee and cacao harvest (and hence low sale price) due to high water content, a problem caused by high humidity in the regions.

The development challenge is defined as follows:

How can we support local economic opportunities for small-scale food producers especially women and indigenous people in North Lombok and Mimika and reduce environmental impacts at the same time?

Two population segments were targeted in the project: women (North Lombok) and indigenous peoples (Mimika) in the fishing and agriculture sectors. Considering the infrastructure component in the possible intervention, we consider four synergistic SDG targets (Table 3). The relevant

Table 1 The role and applicability of core competencies in the context of university-based SDG solution projects

Core competencies and shared learning experience—working definition	Role in the co-creation and engagement process	Application of the process
Design thinking: A process of producing simple and effective responses to complex and ill-defined problems that span disciplines and stakeholder groups	(a) Formulation of identified societal issues as a design challenge and solutions manifested in products, physical environments, services, and/or systems (b) Work out the design challenge throughout iterative phases: understanding the problem, generation of solution alternatives, prototyping and testing, and implementation and evaluation	Students and faculty employ design thinking in a classroom setting that is coupled with consultation with community stakeholders and organizations
Empathy: To understand how others may experience the world from their point of view	(a) As a tool to design SDG solutions in which the emotional feeling is transformed into design attributes (Mattelmäki et al. 2014) (b) As a way to acquire insight into communities' needs that are often concealed. Putting oneself in someone else's shoes enables insights beyond what people say to what they think and feel	Students use empathic techniques, such as an empathy map or photo journal (Ideo 2020), to better identify needs and requirements of the target community that are often hidden/unspoken
Conflict management: The practice of being able to identify and handle conflicts sensibly, fairly, and effectively to minimize negativity and achieve a positive outcome	As mechanisms to cope with expectations ("who gets what") and self-interests of various elements of all the stakeholders. Modes of conflict management include accommodating, avoiding, collaborating, competing, and compromising (Thomas and Kilmann 2007)	Students are exposed to power structure within the community and learn how to deal with competing interests and disagreements during stakeholders' interactions and implementation of a solution
Problem solving: The process of finding solutions to complex societal issues	Facilitate toward being an effective practitioner by solving "real-life" problems in "real time" within communities, given their socio-political dynamics	Students, faculty, and community members work together to solve various unanticipated issues as they emerge during the pilot phase (in the classroom setting) and full implementation (in community setting)
Trust building: Developing a mutual understanding between people in a non-judgmental way so that they can work effectively	Facilitate an effective knowledge exchange for co-creation of solutions (Boschetti et al. 2016), which becomes more challenging when different cultures among stakeholders are involved, especially in an international setting (Ajmal 2015)	Students, faculty, and community develop well-functioning, long-term relationships
Immersive experience: Being physically present alongside stakeholders and being part of their cultural and professional activities	(a) A way to develop more comprehensive means of understanding stakeholder partners (Zoltowski et al. 2014) (b) Through immersion with stakeholders, students gain critical experience in confronting assumptions and prejudices	Students are physically present where the communities and stakeholders live and work through internship programs and international trips to experience the culture of a partner community
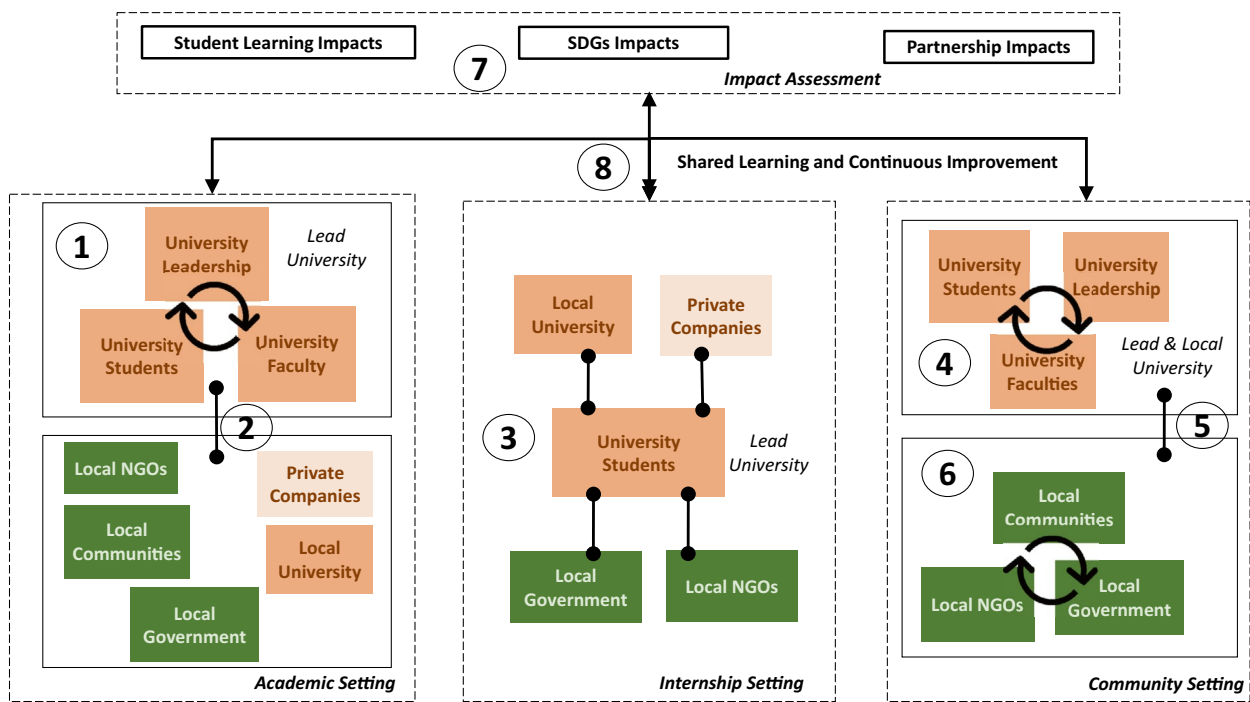
Note: The steps (shown as numbers in the figure) are explained in the text and in Table 2.

Fig. 2 A working model of university-led human-centered design and shared-action learning processes to solve SDG challenges. The steps (shown as numbers in the figure) are explained in the text and in Table 2

Table 2 HCD-SAL sub-processes, key activities, and supports

Sub-process	Key activities	Support of information, funding, and materials
(1) Internal- university learning and support	Conduct SDG solution design courses Provide support for faculty initiatives Establish support for student initiatives	Information sharing on university-wide community development initiatives, a community of like-minded students and faculties, travel and start-up funding
(2) Stakeholders consultation on problem definition and solution ideas	Consultation with stakeholders on the design ideas Test preliminary solution prototype in a classroom setting and get feedback for solution refinement	Information about community needs, preferences, constraints
(3) Embedded placement within stakeholders' institution	Engage students with real-world actors Expose to real-world environment and challenges	Funding and logistical support, community data
(4) Prototyping of implementation	Perform all checks and tests to adjust solution implementation Consider options for improving solutions	Funding, testing facility, communication and logistical support
(5) Co-implementation and transfer of the solution	Organize conditions necessary for solution implementation Transfer the solution ownership and responsibility to the local actors	Materials and supplies
(6) Sustaining performance	Build capacity to operate and maintain the implemented solution Coordinate among local actors for operations and maintenance	Equipment and materials, maintenance training, communication support
(7) Impact assessment	Measure impacts of the solution	Performance data
(8) Shared learning and continuous improvement	Evaluate the effectiveness of the solution Consider and implement options for improvement	Feedback and ideas for further solution improvement

indicators are adopted from the UN official list of target and indicators (UNSD 2021). One common theme across the targets is access to economic resources. The impacts on human health (SDG 3) and education quality (SDG4) were excluded from this study because such impacts can only be measured and evaluated in a relatively longer timeframe beyond the scope of the project.

Stakeholders

Arizona State University (ASU) in the US is the lead stakeholder in the case study, and it is well positioned for this role. Its charter declares, "ASU is a comprehensive public research university, measured not by whom it excludes, but by whom it includes and how they succeed; advancing research and discovery of public value; and *assuming fundamental responsibility for the economic, social, cultural and overall health of the communities it serves*."

The university provides start-up funds to initiate sustainable projects and international travel. One notable example is Changemaker Central @ ASU, whose Change-Agents programs educate and inspire students to become involved in the community through a variety of pathways to affect local and global change. It also provides financial support through community action grants. Furthermore, the School of Sustainability (SOS) established two

internship programs, one linking students and practitioners (i.e., the Frasier Global Mentorship Program) and the other through more research-oriented activities focusing on community development with local stakeholders (i.e., the USAID Global Development Research program).

The lead university also provides incentives for faculty members to team up to offer workshop courses that are oriented toward finding solutions to societal problems. Each faculty member has his/her own individual project and student team to supervise but benefits from sharing resources (e.g., course materials and guest speakers). Students from across projects learn from each other's experiences through regular progress presentations and reflections. Such initiatives receive positive recognition in faculty performance evaluations. Other support includes administrative assistance for getting funding from the private sector and formalizing relationships with local stakeholders (e.g., through a memorandum of understanding, MOU). We established an MOU with the local government of North Lombok and Unram. Diverse societal actors were involved in the project in the two communities (Table 4). Participating students benefit from the university's partnership with Conservation International, which is working to create and strengthen marine protected areas (MPAs) throughout Indonesia. USAID Lestari supports the Government of Indonesia to conserve biodiversity in a carbon rich and biologically significant forest and mangrove ecosystem.

Table 3 Relevant synergistic SDG targets and indicators

SDG target	The emphasis of development goal	Relevant indicators
SDG 1.4	Attainment of equal rights to economic resources for the poor and vulnerable people	Access to economic resources Ownership and control over appropriate new technology
SDG 2.3	Double the income of women, indigenous people, and fishers	Level of income Access to productive resources and inputs
SDG 5.a	Attainment of women's equal rights to economic resources	Access to economic resources
SDG 7.b	Provision of infrastructure for supplying modern and sustainable energy services	Capacity of sustainable energy supply

Table 4 Stakeholders involved in the SDG projects

Actor type	North Lombok	Mimika
Lead university	Arizona State University	
Local university	University of Mataram (Unram)	N/A
Local government	North Lombok Regency (KLU)	Mimika Regency
Private sector	Mining Company Women business NGOs: Wanita Pesisir and Mata Air Laut	Mining company Solar energy company
NGOs	Conservation International	Catholic Church-based NGO: Maria Bintang Laut USAID Lestari
Local communities	Hamlets Karang Kerakas and Gumantar, North Lombok	Hamlets Otakwa and Amungme, Mimika

SDGs projects data sets

Data were collected from focus group discussions (FGDs), community surveys, university course exit surveys, stakeholder interviews, and solutions performance data. Given the relatively small scale and local nature of the SDGs projects, we report a qualitative assessment of SDGs synergistic impacts. Project evaluation is based on the data collected, process documents, observations of interactions (minutes of meetings, personal notes), and student material (project reports and presentations). From the private sector, NGO, and local government perspectives, we conducted post-project interviews and we analyzed published documents, such as company annual reports.

Focus group discussion

A FGD session was conducted in North Lombok (year 1) and in Mimika (year 2). The objective was to assess development issues faced by the local communities and their potential solutions including socioeconomic and ecological factors affecting livelihoods, needs of supporting infrastructure and capacity building, project governance options, and impact measurement mechanisms. Conducting the FGDs in the early phases of the project is crucial in identifying the main SDG focus area and potential synergies. The lead university monitored the development of factors identified in the FGDs annually (the first 2 years in person during site visits, thereafter virtually, due to the pandemic).

The session in North Lombok involved representatives from both the lead and local university's faculties and students, as well as local government units in education, agriculture, and planning (19 participants), and in Mimika, the session involved local NGOs and the mining company's community development unit (14 participants).

Community interviews

The lead university students and faculty conducted semi-structured interviews in year 2 with farmers (6), fishermen (7), and fish sellers (3) in North Lombok (6 female and 10 male) and in Mimika (3 female, 10 male). Interview questions included factors affecting livelihoods, livelihood decisions, and ideas/suggestions for improving livelihood conditions. The responses were voice recorded and tabulated in a spreadsheet.

Community surveys

A survey was conducted of 20 members of two women's NGOs in North Lombok. The survey established the initial condition of the community in terms of level of income and how the income is spent in the households. It was conducted only once at the beginning of the project. All respondents are fish sellers, had a high-school education with age distribution of 20–35 years (5), 36–50 years (12), and 51–65 years (3). Due to time limitation and the difficulty in getting access to members of the local NGO, no community survey was conducted in Mimika.

Solution performance data

Local partners (Unram in Lombok and Maria Bintang Laut in Mimika) provided regular reporting of the technical and production data of the implemented solutions. The data were collected via email and WhatsApp every 6 months.

Workshop course exit survey

Students from the lead university who participated in the sustainable development workshop course were asked to fill out an exit survey at the end of the semester. The questions are designed to evaluate the quality of the process and outcomes including satisfaction with the course, learning impacts, and potential impacts for future career. In total, over the 4-year period, 52 students were involved (33 female and 19 male), of which 37 were undergraduates and 15 graduates.

Results

Application of the HCD-SAL model in the context of university involvement

Academic opportunities (academic setting)

In addition to the financial support noted earlier, the lead university offers two workshop-based design courses on sustainable development: (1) Sustainable Development in Action and (2) Global Resolve: Design for a developing world. The courses are designed to bridge academics and practice by being problem driven, culturally sensitive, and solution oriented. Students engage with national and international development researchers and practitioners to better understand the complexity and inter-connectedness of local to global development challenges, get exposed to the national/international development landscape (key actors, organizations, and institutions), and derive lessons for context-specific solution pathways and transitions. Teams of graduate and senior undergraduate students majoring in sustainability, engineering, and business get the opportunity to work in collaboration with international partners on project design, monitoring, and assessment. In doing so, students will be a part of efforts that can potentially make a real and positive change in the life of people, particularly those who are marginalized.

During the two workshop-based design courses (years 2–4), guided by the stakeholders' specification of the SDG challenges, student teams explored alternative solutions, built prototypes, and tested them. In the process, alternative solutions evolved and were evaluated for technical feasibility and cost-effectiveness. After two years, feasible solutions were identified and implemented in the community. In the case of addressing the need for fish preservation, the initial solutions that were considered included the use of dry ice and a methane-based refrigeration system. Once the prototypes were built and tested, such solutions were deemed technically and financially infeasible. The most feasible solution that was eventually implemented was a solar photovoltaic (PV) system facility for ice making (Fig. 3a).

In the case of addressing farmers' need for crop harvest processing, the first group of student teams came up with a crop dryer design that consists of a greenhouse to trap heat and a fan to circulate air. The motivation was to use the latest technological innovations. After further consultation with stakeholders, such a design was deemed logistically infeasible especially in Mimika where the mountainous terrain poses challenges for transporting the required materials. Based on this feedback, the next group of students developed an alternative solution for a cocoa and coffee dryer that is low cost and easily transportable, uses (mostly) local materials, requires low maintenance, and uses solar energy instead of electricity to operate (Fig. 4).

Stakeholders consultation on problem definition and solution ideas (academic setting)

During the conduct of the workshop courses, intensive consultations with all stakeholders took place. During the exploration of needs and generation of solution ideas, the students developed empathy (i.e., what the communities say, do, think, and feel) based on a card-sort technique (i.e., using picture cards to sort priorities), photo journals, questionnaires, interviews, and videos about local communities (both from the internet and of our own production). During the prototyping phase of the solar-powered icemaker solution, the student team received feedback from a solar energy TNC on how to design the system. The company also donated some solar PV panels as part of their corporate social responsibility (CSR) initiatives. We employed all communication channels that were available to us. One of the most reliable, especially for local

Fig. 3 The implemented solar photovoltaic (PV) system facility for ice making for fishermen (Source: author's collection)

(a) North Lombok

(b) Mimika

Fig. 4 Cocoa and coffee solar dryer design and implemented solution (source: author's collection)
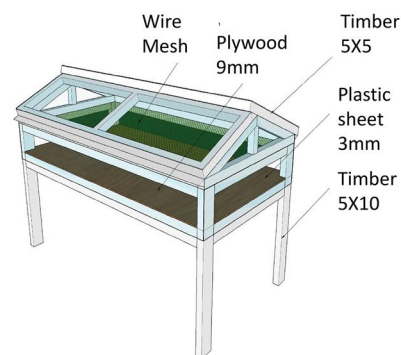
(a) Student design concept of cocoa and coffee solar dryer with information on materials used.

(b) Implemented solar dryer solution for cocoa farmers in Mimika.

communities, was the WhatsApp application, given the wide use of smartphones and availability of internet connection in Indonesia.

Embedded placement within stakeholder institutions (internship setting)

The students were embedded in private companies, as well as local universities and governments, allowing for more regular and intensive interaction. An internship with the mining company was facilitated through the Frasier Global Mentorship Program. The program offers university students and professional sustainability practitioners the opportunity to engage in an insightful mentorship experience. Our students were paired with sustainability professionals from international or globally focused organizations. The program culminates in an immersive on-site experience, providing the student mentees the opportunity to visit their mentor on site or attend a professional development-related conference.

The students were also embedded in the local university, NGOs, and government through the USAID Global Development Research program. The program was created to cultivate global research collaboration and offer fellowships that leverage the expertise of graduate students. This partnership contributes to solutions for complex development challenges and enhances capacity in developing countries by allowing students to match with a host organization.

Exposure to real-world environment and challenges. Throughout the internships, students conducted interviews and focus group discussion sessions with the various

agencies within the government of North Lombok (KLU). The Unram team assisted in data collection.

Prototyping the implementation (community setting)

Perform all checks and tests to adjust solution prototype. Before the actual implementation of the solar-powered ice-maker system, students and faculty members from both universities worked together to prepare the setups, which included considering different scenarios of how the implementation could go wrong. Students at the local university played an important role. They provided a cultural bridge by acting as English language interpreters and facilitators during stakeholder interactions.

Consider options for improving solutions. Based on the performance feedback of the solar panels and batteries, the universities and the Catholic Church team held brainstorming sessions on how to maintain and improve the performance of the solar-powered ice-making and crop processing facilities.

Co-implementing and transferring the solution (community setting)

Organize conditions necessary for implementation. The lead university team conducted intensive consultation with the local communities to prepare the facility for the North Lombok site (Fig. 5a). In the case of Mimika, the advanced team of the cooperative run by the Catholic Church helped prepare the site prior to installation. Both the local government in North Lombok and the cooperative contributed by allocating land and building the foundation for the solar PV panels. The energy company donated solar PV panels for the Mimika facility while the mining company funded the

Fig. 5 Stakeholder interactions in the community setting in North Lombok (source: author's collection)

(a) A consultation meeting with women NGO representatives to coordinate operations of solar PV-based ice-making facility

(b) A dialog and official hand over of the facility attended by the lead university team (in yellow) and Unram, the community members and the head of the North Lombok regency

implementation of the ice-making and crop dryer systems in North Lombok and Mimika. All of these activities were coordinated by the lead university.

Transfer of solution ownership and responsibility to the local actors. The ice-maker operations were transferred to the women business empowerment NGO (North Lombok) and Catholic Church NGO (Papua) (Fig. 5b). The overall responsibility was also shared with the local government (North Lombok) and the mining company (in Papua).

Sustaining performance (community setting)

Build capacity to operate and maintain implemented solution. The universities' team developed a training module for maintaining the facility. In the case of Mimika, NGO personnel were dedicated to maintaining the facility.

Coordinate among local actors for operations and maintenance. The local NGOs and university monitor the performance of the solutions and share information regularly with the lead university team.

Impact assessment

The faculty at the lead university established a system for monitoring of impacts across all stakeholder participants. We focused on three aspects: student learning, partnership, and community impacts. These include students' learning outcomes, environmental impacts, perceived costs and benefits, and ultimately how the projects helped increase the communities' economic opportunities. The details of the impact assessment are described in the subsequent section.

Shared learning and continuous improvement (cross-cutting settings)

Evaluate the effectiveness of the solution. The process allowed for shared learning and monitoring impacts across all stakeholder participants. The academic, internship, and community setting are interrelated in a way that experience in one setting affects adjustments in others. Occurrences of conflict of interest among community members during implementation led to the addition of a module on conflict management and cultural sensitivity in the workshop course. Students and faculty interactions with stakeholders during internships help improve personal relationships, which facilitates better consultation in the academic and community setting. Throughout the process, some preliminary solutions for fish preservation (dry ice and ammonia-based system) were challenged by the local university and NGO partners, shaping design ideas toward solutions that were more practical and reliable (solar PV-based system), given the local community contexts. Over a relatively long-term

period, these interconnections create positive feedback loops for reflection and improvement.

Consider and implement options for improvements. The solar PV-based systems also evolved. Based on the evaluation of system performance, the universities' team installed reflectors around the PV panels, which increase electricity generation by up to 30%, especially during cloudy days (Fig. 6).

The next evolution for the whole initiative is establishing an NGO that is associated with the universities. Two former student alumni of the program created an NGO that focuses on supporting sustainable development efforts in Lombok.

Evaluation of SDG impacts

In Northern Lombok, the solar-powered facility produces 180 kg of ice per day (on the best days) and is run by two NGOs focused on women's empowerment. Ice sales translate into total additional monthly income for the NGOs' members of Rp. 4.5 million (about $310). The income generated by ice-making and crop dryer facilities has increased but has not yet doubled due to the small scale of the project. In Mimika, the solar-PV facility replaces a diesel-powered generator, resulting in a monthly saving of 119 gallons of diesel, for a monthly saving of Rp. 4.3 million ($295), as well a reduction in carbon emissions of about 1200 kg per month. The solar coffee and cocoa dryer solution cuts the drying time by two days. Reduced water content in the beans increases the market price by $0.15 per kg and hence results in higher income.

The results of the survey with the 20 women NGO members in North Lombok revealed that some use their income solely for providing food (5 people), solely for education (4 people), on both food and education (9 people), while two

Fig. 6 Sun reflector add-ons to the North Lombok facility resulting from continuous feedback for improvement (source: author's collection)

people provided no response. Thus, these additional supports can improve children's overall health and school completion rate in the long run. The PV-based production system also became a foundation for an expansion of economic activities in Mimika (SDG 8). The cooperative is now building a community store providing basic goods to create an economic hub for the surrounding areas that are isolated from major economic centers (Fig. 7).

An assessment of the SDGs synergistic impacts is based on the scale proposed by Nilsson et al. (2016) (Table 5). Overall, interactions of the SDG targets involved positive synergistic interactions by giving women and indigenous people access to production resources.

Reflections from the case study

Reflecting upon the experience at the lead university, we identify some general challenges that need to be overcome and some necessary conditions, incentives, and supporting systems that need to be in place for successful SDG

Fig. 7 A community store under construction in Mimika, Papua that builds on the availability of solar energy (source: Maria Bintang Laut, NGO)

resolution (see Supplementary Information, Table S1). Overall, establishing and implementing SDGs stakeholders' engagement through an HCD-SAL model entails an investment in building long-term relationships and commitment through an iterative and often trial-and-error process. Communication and information channels (e.g., through WhatsApp and Zoom) need to be set up at early stages to reduce coordination and transaction costs across all the sub-processes. Cultural differences and language barriers can be addressed by development of cultural awareness for students within universities and having facilitators with the local actors. To the challenge of continuity of funding, universities may have to provide seed funding for international travel and start-ups. They can support faculties developing proposals to get funding from private companies through their CSR initiatives.

The fact that the flow of students, faculties, administrators, and administrative staff is dynamic poses a challenge to the long-term continuity of SDG initiatives. Students typically enroll in a course for only one semester (too short for achieving significant results) and self-select the courses (qualifications not fully aligned with project needs). To mitigate this challenge, paid student positions can be created outside of the classroom setting to fill the expertise gaps and maintain momentum and students can be allowed to enroll in a class twice. The teaching process can be initiated by a single faculty who is willing to adopt the human-centered design framework. As the course evolves and shows positive impacts, it would attract the involvement of more faculty members and support from the university. Continuity is more easily maintained if the faculty members involved receive the right incentives (e.g., seed funding and positive faculty evaluation review) from administrators.

For sub-processes in the partnership setting, the main challenge involves setting up internship programs and maintaining partners' commitment. In general, private companies, especially TNCs, are well positioned to work with

Table 5 Evidence of synergies among relevant SDG targets

SDG target pairs	Synergistic interaction scale	Evaluation of synergies
SDG 1.4 and 2.3	+ 3 (indivisible)	The transfer of facility ownership to the NGOs and cooperatives provides immediate income generating resources for the poor and the indigenous people
SDG 1.4 and 5.a	+ 2 (reinforcing)	Giving women who are poor access to production resources makes it easier for them to allocate additional income to food and education
SDG 1.4 and 7.b	+ 1 (enabling)	The supply of renewable energy that is reliable creates conditions for supporting economic activities for preserving fish and crop drying
SDG 2.3 and 5.a	+ 2 (reinforcing)	The women NGO groups have control of the solar-powered ice-making facility that helps increase their income which supplements food and education
SDG 2.3 and 7.a	+ 1 (enabling)	Solar-powered production facilities create conditions in which fishermen and farmers avoid paying for electricity, hence boosting their income
SDG 5.a and 7.a	+ 1 (enabling)	The ice-making system improves women NGOs' access to economic resources

Impacts on students' learning and partnerships are described in the supplementary information (SI)

student interns, as long as the program fits into their mission and the country in which they operate. Aligning the program with corporate social responsibility (CSR) initiatives will greatly increase the chance of sustaining the program.

For local universities, an international collaboration is considered one key factor in driving the quality of their research and education and will get them government's recognition since the efforts are aligned with government economic and human development policies. For the lead university, they have the scope and expertise to accommodate project needs and can help establish a connection with local governments and NGOs. Faculty members' personal relationships between lead and local partner universities can help initiate a partnership before it can be formalized through an MoU. Based on trust, such partnerships can facilitate more genuine and effective engagement.

In the community setting, to ensure the sharing of responsibilities and accountability for progress toward meeting the SDGs, it is important to have a transparent governance mechanism to hold each other to account to make sure that the SDGs solutions are actually being sustained. To create a strong and long-lasting bonding between students and communities, students should stay wherever and whenever it is safe to do so within the community (e.g., a homestay arrangement as opposed to being in the community only during the day and staying elsewhere during the night). To facilitate a cross-pollination of solutions across different communities, a repository of knowledge and solution prototypes can be established. A feedback mechanism involving all stakeholders would need to be established to detect signs of deterioration of solution performance and identify ideas for improvement.

Discussion

Opportunities for learning from best practices across universities

Although the study is centered on the experience and setting at the lead university, there is ample room to learn best practices from each other and adapt them to one's own contexts. Various universities' initiatives to support sustainable development include those in Europe: University of Gratz, (Sedlacek 2013), ETH Zürich, the University of Zürich, the University of St. Gallen (Brundiers and Wiek 2011), and Plymouth University (Purcell et al. 2019); and in the US: Harvard University (Purcell et al. 2019) and Oberlin College (Daneri et al. 2015). The fact that many universities are embedded in inter-university networks regionally and globally provides a clear opportunity to establish partnerships between universities, especially those in the developed

countries with those in developing economies mostly in Asia, Africa, and South America.

Aligning local SDGs efforts with national/global context

As SDG implementation occurs across multiple scales, it is important to consider how the efforts that were initiated at a local level can complement and augment achievement at the national and global level (i.e., localizing the SDGs) (UN Development Group. 2014; Sterling et al. 2020). Although the implementation of the 2030 Agenda is mostly top-down driven and takes place mainly at the national level, the achievement of SDGs depends strongly on progress made at the local level (Oosterhof 2018). By design, most university-led SDG initiatives involving students take place locally in an environment where university and societal actors interact under unique socioeconomic conditions. The localized SDGs initiatives and efforts as illustrated in the study could play some important roles in supporting successful SDGs implementations. First, universities' initiatives serve as seed projects, which if successful, could trigger a snowball effect by persuading others to emulate these activities, hence catalyzing further transformation (Smith et al. 2018). Second, for private sector funders, the seed projects serve as a test case influencing where they should prioritize funding. Third, the co-created solutions and knowledge, when disseminated by universities across broad stakeholders, can drive actions beyond the initial scope of SDGs areas.

Aligning the project with the national/global context first requires that during the initiation of a project, all parties should identify and agree on a subset of SDGs that are relevant to the targeted community. Next is to develop shared narratives on how the locally specific projects create pathways towards achieving national/global goals (Szetey et al. 2021). The development of the pathways entails an understanding of how regional/national socioeconomic drivers influence local sustainability and vice versa. In the case of North Lombok and Mimika, the pathways should lead to individual project impacts that improve the currently low HDI and SDG index ratings at the provincial and national levels. The impacts of local projects will eventually need to be entered into the national SDG reporting system (Bexell and Jönsson 2019; https://unstats.un.org/sdgs/unct-toolkit/) and be linked to other ongoing initiatives. Such efforts depend on the statistical capacity of local–regional governments to collect data, monitor performance, and evaluate overall SDGs progress. At the global level, representatives from all levels of governments, civil society, private sector, academia, and other stakeholders join the UN High-Level Political Forum on Sustainable Development (HLPF) annually to evaluate the progress made in achieving the SDGs.

The reporting to the UN on national level advancement toward fulfillment of the SDGs is, however, still voluntary.

Concluding remarks

The UN SDGs agenda has progressed over the past five years. Given this context, this study addresses the need for a better understanding of the synergies between SDGs. At a community level, development challenges present opportunities for universities to harness SDGs synergies through co-creation of solutions and an implementation process. Building upon the co-creation concept and prevailing practices, our case study presents a model to operationalize such a process.

The COVID-19 pandemic has significantly setback countries' SDGs achievements (Sachs et al. 2021). Future work will have to deal with the post-COVID world. There have been questions as to whether the current SDGs are still relevant in the wake of the pandemic and calls for revision (Naidoo and Fisher 2020). A post-pandemic world also, however, provides a great opportunity to build a more sustainable future for the community in need (Ottersen and Engebretsen 2020). In this debate, we tend to agree with the latter. Our experience suggests that we should continue university-led efforts to push the agenda forward by designing and implementing more effective solutions at the local community level. In addition to SDG synergies, the model needs to tackle the trade-offs among different solutions, most prominently that greater economic opportunities may result in environmental degradation.

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