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Teaching Sustainable Frugal Innovation Development to Business Students

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Abstract
Frugal innovations have the potential to address social, ecological, and economic issues. Students as future engineers and managers can play an important role to foster frugal innovations. Previous research related to the teaching of frugal innovation in higher education focus primarily on engineering and design study courses. There are no publications how to teach the concept of frugal innovation to future managers respectively, to students of the economic/business sciences. I introduce and evaluate a new concept for teaching sustainable frugal innovation to business students by means of LEGO® SERIOUS PLAY® and Design Thinking. Design Thinking as a concrete innovation method supports the sustainable frugal innovation development process and LEGO® SERIOUS PLAY® as a method of playful learning and creative education provides a less technological access for the business students to innovation development. I present concrete results of the innovation development of a TV for elderly and sustainability-conscious people. The social aspects of the developed TV addresses identified needs of elderly people for self-determination, social integration, and not feeling lonely. Regarding ecological aspects, the developed innovation addresses the four key circular economy principles: design, reduce, repair and maintenance, and reuse and recycle. Design Thinking is suitable to develop frugal innovations, due to the customer focus is emphasized in the empathize- and define-phase and highly relevant for the analysis of demanded core functionalities and related performance levels of frugal innovations. The here presented concept allows other researchers, lecturers, and practitioners to apply Design Thinking and LEGO® SERIOUS PLAY® for sustainable frugal innovations.

Keywords: Frugal Innovation, Sustainability, Product Development, Higher Education, Business Sciences, LEGO® SERIOUS PLAY®

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1. Introduction

The following paper deals with the research question "How to teach sustainable frugal innovation development to business students?". To define frugal innovation Weyrauch and Herstatt (2016) conducted a comprehensive literature review and suggest three key criteria: substantial cost reduction, concentration on core functionalities, and optimized performance level (Weyrauch and Herstatt, 2016). Frugal innovations can help fighting poverty, building economic growth, addressing various social needs like promoting education or improving health, tackling climate change, and protecting the environment (e.g., Arnold, 2018; Brem and Wolfram, 2014). Most of these (sustainability) issues are addressed by frugal innovation in a developing countries context respectively, emerging markets context. But Kroll and Gabriel (2020) "[…] see [also] considerable potential for frugal innovation to create positive social and economic outcomes in advanced economies. Frugal innovation is promising as a means to avoid addressing problems at the cost of the environment, customer safety and the well-being of populations […]" (p. 49). Frugal innovation in advanced economies can address social-economic and ecological sustainability issues like more affordable products and services for customers or reducing resources in the production process and waste due to more robust and repairable solutions (Albert, 2019).

To harness the (ecological and social-economic) potentials of frugal innovation in advanced economies and to be aware of their pitfalls, like rebound effects or neglecting sustainable issues in all parts of the value chain (e.g., ecological and social unsustainable extraction of raw materials) (Albert, 2019; Hyvärinen, Keskinen, & Varis, 2016), the concept of frugal innovation has to be spread. "[M]otivating German engineers and managers to adopt a "frugal mind-set" as well as to design frugal innovation processes are still challenges to be resolved" (Tiwari et al., 2016). Amongst other relevant stakeholder groups, students as future engineers, designers, and managers can play an important role to foster frugal innovation in advanced economies companies. Improved educational opportunities are necessary to exploit the potentials of frugal innovation and it is important to interdisciplinary mediate core competencies for frugal innovation development (Kalogerakis, Tiwari, & Fischer, 2017).

Previous research relating to the teaching of frugal innovation in higher education focuses primarily on engineering and design study courses and the concrete (manually) creation of frugal innovation solutions (e.g., Fischer et al., 2021; Maertens, et al., 2020; Walden and Lie, 2021; Warner and Caudill; 2013). Although all three occupations of design, engineering and management are emphasized to create frugal innovation (e.g., Kroll and Gabriel, 2020; Tiwari et al., 2016), there are no publications, how to teach the concept of frugal innovation to future managers respectively, to students of the economic/business sciences, who have a less technological focus in their courses than engineering or design students. Also, the economic/business faculties are not equipped like engineering/design faculties. For example, Maertens et al. (2020) describe which kind of technologies students of "Industrial Design Engineering" (Faculty of Engineering and Architecture, Ghent

University, Belgium) use to reach a frugal innovation: injection moulding as service from external companies, 3D printing, CNC machines, metal folding, thermoforming, bending, or metal punching. Most of these technologies are not available to business students and necessary skills to use these technologies are not taught, due to another focus in their studies. Nonetheless, business students as future employees can play a critical role in innovation processes and influence the decision between conventional and frugal innovation in a company's various business units and functions like R&D, (innovation) strategy, (innovation) project management, (innovation project) controlling, market research, marketing, procurement, or production.

To address this research gap, a concept for teaching sustainable frugal innovation development to business students is introduced in this paper and evaluated. For a less technological access to the frugal innovation concept for business students, LEGO® SERIOUS PLAY® (LSP) is incorporated in the teaching concept as well as Design Thinking (DT).

2. Theory

2.1. Frugal innovation development

There are three perspectives on frugal innovation: frugal innovation as process, outcome, or management philosophy. First you can distinguish between frugal innovation as a process of creating an outcome (e.g., engineering process) and frugal innovation as an outcome (e.g., product or service). If you look at the literature related to the creation or development of a frugal innovation outcome (process perspective), you will find many references to concepts such as frugal (new) product development, design for frugality, frugal engineering or constraint-based innovation (e.g., Brem and Wolfram, 2014; Micaëlli, Forest, Bonjour, & Loise, 2016; Rosca and Bendul, 2015). The second distinction is made sometimes between frugal innovation and frugal engineering. Whilst in this case frugal innovation can be understood as a type of management (philosophy), frugal engineering is the process of developing frugal solutions (Brem and Wolfram, 2014; Rosca and Bendul, 2015). In the following the focus lies on a process perspective, hereinafter referred to frugal innovation development.

Cadeddu et al. (2019) present a new product development process for frugal innovation, which consists of four phases and nine stages: Fuzzy Front End (opportunity and idea discovery, opportunity and idea screening), concept development (market study, technical study, concept evaluation), product development (product design, prototype testing), and commercialization (market testing, production ramp-up). Brem, Wimschneider, de Aguiar Dutra, Cubas, and Ribeiro (2020) present a process model for frugal product design development based on the two main phases "need identification" (analysis of frugal target criteria, analysis of social and cultural context needs and conditions, syntheses of analyses) and need integration (product planning, product design development, product tracking and improvement).

To sum up, relevant frugal innovation key criteria, which need to be taught to higher education students are substantial cost reduction, concentration on core functionalities, and optimized performance level (Weyrauch and Herstatt, 2016), and are similar to the ones, which are taught to engineering and design students. As mentioned above, in an advanced economies context, ecological sustainable aspects are also central (Albert, 2019). The integration of "ecological sustainability" as a normative concept in teaching frugal innovation could address this aspect and provide the chance to approach pressing global ecological needs with sustainable frugal innovation (e.g., Albert, 2019; Kroll and Walz, 2020). Relating to frugal innovation development the main phases of the two presented frameworks are similar (Brem et al., 2020; Cadeddu et al., 2019) and are suitable to get taught to higher education students. Simply put, it starts with the generation of ideas and the development of a concept (fuzzy front end) based on market (social and cultural context needs and conditions) and technical studies (frugal target criteria), followed by product development (design, prototyping), and ends with market introduction. Compared to the frugal innovation process, which is taught to engineering and design students, the planned process for business students should also address the market introduction phase as well as related topics like business model or go-to-market-strategy. An aspect, which is not considered in more detail in this paper is the (frugal) manufacturing/production process, which can be also designed to save resources and energy.

2.2. Design Thinking and LEGO® SERIOUS PLAY®

To support the sustainable frugal innovation development with a concrete innovation method, I decided to use DT as a human-centred innovation approach, which focuses on people or customers and their needs rather than on specific technology conditions (Matthews & Wrigley, 2017). This human-centred approach should help to focus on the social needs of the target group of a sustainable frugal innovation, rather than focus only on frugal aspects of a potential solution. Such a focus addresses also two key criteria of frugal innovation: concentration on core functionalities and optimized performance level, derived from the (social) needs of the potential users. DT "[…] uses the designer's sensibility and methods to match people's needs with what is technologically feasible and what a viable business strategy can convert into customer value and market opportunity" (Brown, 2008, p. 2). As a framework for the sustainable frugal innovation development, I integrated the DT process from d.school (Both and Baggereor, 2019) with the five phases empathize, define, ideate, prototype and test. Relating to Both and Baggereor (2019) in the emphatize-phase the designers must understand the way people do things and why, their physical and emotional needs, how they think about the world, and what is meaningful to them. Based on these learning, in the define-phase the designers must make sense of the widespread information they have gathered and define for example the problem statement. Starting from the definition of the design challenge, the designers generate ideas in the ideate-phase. These ideas get transferred in prototypes in the prototype-phase, first quick and cheap, later more refined. These prototypes get tested in the test-phase and designers should

focus on what they can learn about the person and the problem as well as their potential solutions (Both and Baggereor, 2019).

To facilitate the DT process especially in the phases ideating and prototyping, I also integrated LSP in the concept as a less technological access to innovation/product development. Micheli et al. (2019), who undertook a comprehensive literature review of 104 articles (relating to DT) identified creativity and innovation, user centeredness and involvement, and problem solving as the three most common principal outcomes of design thinking. These are aspects, which LSP also addresses.

LSP was developed by Bart Victor and Johan Roos, two professors of leadership and strategy at the International Institute for Management Development in Lausanne, Switzerland, and Kjeld Kirk Kristiansen, former President and CEO of The LEGO® Group (Roos and Victor, 2018). It is an innovative and effective way of exploring complex issues without obvious answers and its purpose was initially to generate more engagement, imagination and playfulness in staff meetings' in the business sector (James, 2013). In higher education, LSP can support the motivation and learning of students. LSP as a method of playful learning and creative education can foster the understanding of concrete topics by enhancing open-mindedness and flexible and critical thinking, support personal growth, team-building/collaboration, and creativity (James, 2013; 2019). The LSP methodology based on several concepts: constructivism/constructionism, the concept of play, storytelling and the use of metaphors, the flow model, and the interconnection between the brain and the hands (Frick et al., 2014; Wengel et al., 2021). LSP offers a means for a group to share ideas, assumptions, and understandings, engage in a rich dialogue and discussion, work out meaningful solutions to problems, and pushes participants to be creative and to find out-of-the-box solutions (Frick et al., 2014). In general, LSP supports creativity and problem solving and has been used at companies worldwide for strategy development and exploration, organizational development, innovation and product development, and change management (LEGO® SERIOUS PLAY®, 2010).

LSP is a structured process organized as a workshop, which is led by a facilitator and can range from 1.5 hours to two days (Kurkovsky, 2015). The facilitator guides the participants (usually four to eight) through activities regarding to use LEGO® bricks to build models representing their thoughts, reflections, and ideas, with the goal of team building, gaining a deeper understanding of a complex problem, or developing a strategy (Frick et al., 2014; Kurkovsky, 2015; LEGO® SERIOUS PLAY®, 2010). There are two versions of LSP: LSP 1.0, which is an open source version and LSP 2.0, which is the version of the Association of Master Trainers in LSP (Wengel, 2020). An LSP workshop consists of three (LSP 1.0) or four steps (LSP 2.0) (Kurkovsky, 2015; LEGO® SERIOUS PLAY®, 2010; Wengel, 2020):

1. Challenge: the facilitator poses a question/challenge;

2. Building: participants build a LEGO® model representing their reflections on the building challenge;

3. Sharing: participants share the meaning and the story that they have assigned to their own models; and

4. Reflection (for LSP 2.0): participants reflect on their understanding of the models and their meanings.

Focusing on teaching innovation development in a higher education context, the following two exemplary studies provide some insights. Zenk et al. (2018) suggest a design for an innovation course in higher education based almost exclusively on LSP to teach the entire cycle of innovation from ideation through prototyping to future scenarios. The courses consist of three units: three hours classroom-based training one (introduction to LSP and innovation research, ideation and prototyping using LSP), three months self-study in teams (develop innovative prototype, write project documentation, create elevator pitch), and three hours classroom-based training two (presentation of prototype, future scenarios and evaluation using LSP). Lear, Dann, and John (2020) present findings relating to the use of LSP in two workshops, one on problem definition and one on solution generation, in a course for the initial development of professional skills for engineering and computing graduate students at the Australian National University. In the course the students are provided (by industry clients) with real-world problems to responsibly innovate and address industry challenges in engineering and computing, using a DT framework supported by LSP. There are no clear statements from Lear et al. (2020) in which DT-phases LSP was concretely used.

To sum up, LSP can be used for teaching innovation development in a higher education context. LSP can be incorporated in a single workshop or time-delayed in different workshops. The incorporation is oriented towards the innovation development phases, for example represented by the DT method, which can provide (as a framework for innovation/product development) a suitable procedure to structure a course. An LSP workshop starts usually with an introduction to the method of LSP (theory, rules, guidelines, and steps) and the goals of the workshop, followed by a series of warm-up tasks (e.g., building, building representations, and building analogies and metaphors) (McCusker, 2014). Relating to the innovation development phases, respectively DT-phases, LSP can be incorporated to explain, discuss, and understand the trigger of the innovation development initiation (e.g., industry challenge, customer/user needs), as well as support the idea generation (and idea assessment), concept development (with product definition and business model), and prototype creation (and prototype evaluation). It is also possible to use LSP for planning the go-to-market strategy (e.g., marketing and sales) (Ematinger and Schulze, 2012).

2.3. Learning objectives

The learning objectives for the students of the seminar relate to frugal innovation and their development (relating to the framework of DT), sustainability, and LSP. They are inspired by Hoque (2016) and embedded in all three domains of learning: cognitive (knowledge) by Bloom et al. (1956), affective (attitudes) by Krathwohl et al. (1964), and psychomotor (skills) by Simpson (1972).

In the **cognitive domain** all six categories should be addressed at the best:

- Knowledge and Comprehension: recall and understand the meaning of sustainability and frugal innovation,
- Application and Analysis: apply the concepts in the development (by means of DT) of sustainable frugal innovation and differentiate non-frugal/non-sustainable aspects,
- Synthesis: create a new sustainable frugal innovation solution (applying the DT-phases), and
- Evaluation: evaluate the positive and negative aspects of frugal innovation development (in the DT-phases).

Relating to the **affective domain** all five categories should be addressed at the best:

- Receiving: be aware of frugal innovation and sustainability,
- Responding: participate actively in the sustainable frugal innovation development,
- Valuing: see the worth of addressing social and ecological issues in daily life and working (e.g., by means of frugal innovation),
- Organization: prioritize social and ecological aspects in frugal innovation development, and
- Characterization: internalize social and ecological values (personal attitude change).

The **psychomotor domain** is linked with the building with LEGO® bricks in (sustainable) frugal innovation development and consists of learning objectives in the first five of seven categories at the best:

- Perception: building with LEGO® bricks,
- Set: building with LEGO® bricks in the sustainable frugal innovation development (respectively, in the different DT-phases),
- Guided Response: following the instruction given by the LSP facilitator, while using LEGO® bricks in sustainable frugal innovation development (respectively, in the different DT-phases),
- Mechanism: come up with purposeful LEGO® models for sustainable frugal innovation development, and
- Complex Overt Response: able to skillfully perform in the LSP-process (building really good LEGO® models, functional and aesthetic).

Also learning objectives in the next two categories of the psychomotor domain (Adaption and Origination) can be addressed on a second level, when students see the usefulness of LSP and are motivated to apply LSP in their future working life or working on other topics with LSP in studying life for example.

3. Methods

3.1. Evaluation

The goal relating to the evaluation is to assess the suitability of the seminar concept to teach sustainable frugal innovation and their development to business students. The cognitive and (partly the) affective domains of learning were evaluated with an ex-ante and ex-post questionnaire and the affective and psychomotor domains with a survey. The ex-ante questionnaire was created to find out the students' knowledge about frugal innovation and sustainability before they deal with these topics in the seminar. For better comparisons of the learning outcomes of the participating students the ex-ante and ex-post questionnaire contain the same questions based on the learning objectives. The questionnaire and the survey are based on descriptions, explanations, sample questions, and keywords from Horner, Zavodska, and Rushing (2005) (address the cognitive domain), Lochotinant and Yanchinda (2019) (address the psychomotor domain), and Syaiful, Ismail, and Abd Aziz (2019) (address the affective domain). To get unbiased answers in the ex-ante questionnaire for the cognitive domain, the seminar description was rather general, and the students did not know about the concrete type of innovation (frugal) as topic of the seminar (but they know, that the seminar deals with sustainability).

In the first session, after completing the questionnaire about the cognitive domain, the seminar structure, goals, and sessions were presented. A lecture was given to the students on DT and LSP, frugal innovation and their development, and sustainability and circular economy. The ex-ante evaluation of the affective domain (relating to frugal innovation and sustainability) was following in the first session (so you can measure the students "Receiving", in other words, if the students were interested and paid attention to the lecture). As the affective and psychomotor domains cannot be inquired sufficiently enough through a questionnaire, the students development relating to these both domains were surveyed throughout the seminar. The survey protocol relates to the learning objectives and is also based on the descriptions, explanations, and keywords from the aforementioned authors. The process of the students relating to the different categories of the affective and psychomotor domains were rated per session (starting with session two for the psychomotor domain and session three for the affective domain) on a scale from one to five with additional written feedback from the lecturer of the seminar and a second observer.

3.2. Sample

The teaching took place in a university in Germany. The sample group consisted of Bachelor students of Business Administration (B.Sc.) and Business Administration and

Engineering (B.Sc.). The teaching concept was embedded in the teaching format of a one semester (half-year) seminar (elective subject) for six to ten students. At the end, nine students participated in the seminar. Four students studied Business Administration (B.Sc.) and five students Business Administration and Engineering (B.Sc.). Six students were in their fifth semester of study, two in their sixth, and one in the seventh. The age of the participating students ranged from 20 until 24 with a mean at 22 and four female and five male students participated. As the sample size was only nine, it was not statistical representative.

In the seminar the students were asked about their relation, reasons for selecting the seminar, and previous experience with building with LEGO®. From the nine participants three groups (consisting of two, three, and four people) knew each other before the seminar. Reasons for choosing the seminar (multiple answers allowed) were building with LEGO® seven times, dealing with sustainability four times, and seven times, that the seminar as comprehensive package was the best alternative from the various offerings. All students built with LEGO® before (especially in their childhood) and three students had actual building experiences.

4. Results

The seminar took overall 15 hours and 20 minutes for six sessions and without the evaluations 14 hours. The seminar started with a launch event, including a round of personal introductions, the ex-ante evaluations (see section “Evaluation”) and a one-hour lecture on DT and LSP, frugal innovation and their development, and sustainability and circular economy. DT, the concrete method of LSP, and frugal innovation were unknown to the students. They were sensitized to sustainability (in their daily life), but only half of them heard of sustainability in university lectures or knew the concept of sustainability in more detail (e.g., relate the three dimensions ecological, social, and economic to the concept).

The following sessions were based on the DT-process from d.school (Both and Baggereor, 2019) with the five phases empathize (section: initial problem and needs analysis), define (section: needs analysis), ideate (section: idea generation and concept development), prototype (section: prototyping) and test (section: testing). In the second session “Empathize” the method of LSP, and goals of the LSP workshop were presented, and LSP warm-up tasks were conducted by the students. The warm-up tasks consisted of technical skills building (individual building and building together a tower), metaphoric skills building (individual connecting of five stones relating to the topic of cooking), and storytelling skills building (individual building of dream group work, building together dream group work, and building and placing together external influencing factors relating to dream group work). This exercise (building and discussing the dream group work) also helped the students to gain a common understanding of their group work and relating individual important aspects. Afterwards the students discussed the initial problem of the seminar.

4.1. Initial problem

To choose an initial problem for the seminar, various German target groups were discussed, which deal with social issues, like migrants (racism, integration), children (with poorer educational opportunities), or elderly people (poverty, isolation, lack of participation). At the end, the students choose elderly people (65 years or older) as target group, which represent 18,3 million in 2020 or 22 % of the total German population (predicted 29% in 2030) (Statista, 2023). The at-risk-of-poverty rate (indicator for measuring relative income poverty) lies for German elderly people at 16,4% in 2020 (increase from 11% in 2005) and thus relate to approximately three million elderly people in Germany (Destatis, 2020). The material deprivation rate (indicator for various financial problems and the lack of different technologies in a household, like paying the rent, heating to an acceptable standard, or lack of a TV or a washing machine) lies for elderly people at 2,2 % in 2019, which are approximately 400.000 elderly people in Germany (Destatis, 2023). Besides these social-economic issues, also (hyper-) complex technologies respectively, over-engineered products can be a challenge for elderly people in relation to the technology operation: "[…] older generations sometimes also wish to simplify their lives because they feel overstrained by the complexity inherent in their lives and the products surrounding them. […] Hence, frugal solutions based on their actual needs and easy-to-use products will probably be highly valued by many from this section of the population" (Tiwari et al., 2017, p. 12).

After the decision for elderly people as target group, the students built and discussed various technologies respectively, products, which can be problematic for elderly people due to complexity, e.g., smartphones, cameras, washing machines, or TVs. The students saw the most potential for a frugal innovation in the development of an adjusted TV. At the end of the second session, the students got the assignment to conduct qualitative observation interviews to research the use of a TV by elderly people (eleven observation interviews in total). Observation interviews are a combination of observation (e.g., observing the various steps when using a product) and expert-interview (e.g., asking why a person conducts this step in this manner) (Kuhlmann, 2009).

4.2. Needs analysis

In the third session "Define", based on the results from the observation interviews, the students built with LEGO® (every time first individual and afterwards together) a persona, a story map, and a problem statement. As persona a still independent 75-year-old widow was defined, which is visual- and hearing-impaired (and has also other health issues), has no technical skills, but is interested in technologies like the internet, and gets supported (e.g., on technical matters) by her children and grandchildren. She lives in her own rented apartment (the same, where they raised her children with her late husband) and has a small pension and few savings.

To define the story map, the students used the different job steps (defining, identifying, preparing, confirming, executing, monitoring, modifying, and concluding) from the Jobs-to-be-Done-framework (Bettencourt and Ulwick, 2008) as a basis. Apart from the job-steps relating to using a TV other important issues relate to the purchase of the TV, initial setup, streaming, media library, and peripherals. The following problem statement was defined: "A 75-year-old female pensioner wants through an easy-to-use TV to be entertained and informed to feel self-determined, not lonely and socially integrated". Easy-to-use relates to feel self-determined (some of the interviewed elders felt "kidded" by existing senior remote controls), to be entertained relates to feel not lonely, and to be informed relates to feel socially integrated. As assignment, the students had to research market context, competitors, sustainable aspects, and frugal target criteria, relating to TVs for elderly people.

4.3. Idea generation and concept development

In the fourth session "Ideate" the students generated and discussed together ideas to address the various pain points from the persona relating to using a TV and other related issues. For example, issues relating to visual-impairment should get addressed by a brightness sensor in the TV, Full HD resolution (until 50 inch), a zoom function in the remote control, e.g., for text overlays in the news (where you can point with your remote control on the TV and the section gets enlarged, and also works when you point outside of the TV), an illuminated remote control (controlled through a position sensor), and voice control (so, the elderly people do not rely on the remote control only). Relating to hearing-impairment, it should be possible to link a hearing aid to the TV, for example through a button on the remote control or through voice control. The students also considered sustainable and frugal criteria, especially after rethinking and remodeling the selected solutions with the creative technique SCAMPER: substitute, combine, adapt, modify, put to another use, eliminate, and rearrange (Eberle, 2008). Relating to frugal criteria, the students noticed that a real frugal solution for only watching TV was not demanded by their interview partners. The interview partners also wanted to use some smart TV functions, like media libraries or streaming services. But the students developed solutions which are best possible frugal, e.g., only Full HD until 50 inch (and not all TV sizes with 4K) or omitting various audio- and visual-functions (like HDR or Dolby Atmos). Also, the criteria easy-to-use from the problem statement, which is also a frugal attribute category (together with "user-friendly"), had a big influence on ideas and product specifications and lead to simplified solutions. For example, the remote control should consist of fewer buttons, USB and HDMI ports (for connecting Laptops or USB-sticks with photos from the children and grandchildren) should be accessible from the front, the TV menu should consist of large tiles, whereby the number of them are determined in the initial setup (to keep the menu simple), which should be a guided tour with easy questions or can be supported by the TV company (as extra service). Apart from frugal criteria, also sustainable aspects of the TV relating to its product life cycle were discussed and modeled, like fair social and ecological procurement, manufacturing, purchase, operation (addressed by up-to-date power saving hardware and software), and use

afterwards. At the end of the fourth session the students got the assignment to research product concept and business model in general.

4.4. Prototyping

In the fifth session "Prototype", the students built a prototype, based on the ideas from the last session. They were encouraged to consider the principles of circular economy - design, reduce, repair and maintenance, and reuse and recycle (Levänen, Park, & Rosca, 2022) - when modelling the prototype. The students built prototypes for the TV, external power supply, TV menu, remote control, and packaging. The main feature of the TV is the modularity of various components: TV housing, rotatable foot with a shell for induction charging of the remote control, external power supply, (front) loudspeakers, ports, panel, and mainboard. Especially due to an interchangeable mainboard with free slots, similar to a computer, the TV should be upgradable. For easier repairability each module has a LED which indicates which module is broken and needs replacement. The modules are mainly plugged together, so that an exchange of a module is also feasible for inexperienced people. Apart from modularity and upgradeability the students also considered other aspects of sustainability. They thought about various materials for the TV and decided to use a recycled one-type plastic system. For packaging and the brackets inside they want to use recycled cardboard, adjusted to the size of the TV, with minimal printing and a pull tab on one side (to preclude the likelihood of confusion). As panel guard the students researched an adaptable material from polyethylene and cane.

When discussing the product concept and business model, the facts attracted attention, that a TV with such product features addresses apart from elderly people also visual- or hearing-impaired people and social and ecological sustainable-oriented people, so that these groups become the second and third main target groups of the TV. Relating to earning opportunities the students discussed apart from selling the TV, the selling of individual modules when upgrading or repairing the TV, an offer for the initial setup (including the registration for streaming services), a repairing service (for example with special licensing to TV technicians and thus a lower price for the clients as social sustainable aspect), or the taking-back of old appliances (if the customer does not want to upgrade) with remanufacturing these old TVs and selling them as refurbished TVs for a lower price. A price estimation was not possible for the students, because they could not estimate the material and manufacturing costs. The only indication relating to this topic was the willingness to pay approximately 600 Euro by the main target group, the elderly people, identified in the interviews. At the end of the prototyping-session, the students got the assignment to research a go-to-market-strategy, create a storyboard for the prototype, and conduct interviews to test/evaluate the prototype (seven interviews in total).

4.5. Testing and market introduction

In the sixth session "Test" the intention was to adjust the prototype, based on the results from the interviews. The interviews, which were conducted with pictures from

the prototype and a story map for using it, did only bring one new finding for adjustment, namely a vibrating remote control as another feedback opportunity apart from visual feedback from the TV menu or audio feedback (e.g., a sound). Backlighting of the TV for dark spaces (e.g., in the night) were mentioned once from an interview partner, but the students decided to not integrate such a feature. Relating to the prototype, especially product features like an illuminated remote control, voice control, support for the initial setup, slim/ frugal TV main menu, and the sustainability of the TV through the modular construction went down well with the interview partners. After the discussion of the results of the interviews and the necessary adjustments to the prototype, the students discussed the go-to-market-strategy. Apart from aforementioned aspects like the target groups or business model aspects, the students discussed for example marketing aspects, like price, product, place, and promotion, and time to market. The benefit promises, which also induces the product message, relates to an easy-to-use and sustainable TV. The time to market was estimated with two to three years, when the development-project will be supported with knowledge (e.g., relating to social and ecological sustainable procurement) by existing firms (for example from Fairphone, a Dutch designer and producer of smartphones with the goal of having a lower environmental footprint and better social impact than conventional ones). The production should be outsourced to social and ecological sustainable manufacturers, so only the final assembly will remain. At the end of the session the seminar got oral and written evaluated overall and the ex-post evaluation of the cognitive and affective domains relating to the learning objectives were conducted. The session closed with the presentation and discussion of the seminar report requirements.

4.6. Frugality and sustainability of the developed solution

Relating to the three key criteria, which determine frugal innovation (Weyrauch and Herstatt, 2016), the prototype of the students addresses mainly two of them: concentration on core functionalities and optimized performance level. Concentration on core functionalities is compared with current solutions available on the concerned market (Weyrauch and Herstatt, 2016). The prototype focuses on the essentials, which were identified and evaluated in the (observation) interviews. It is not a "TV-only" device, due to the interview partners also wanted to use some smart TV functions. But the prototype is user-friendly, easy to use, and has a reduced complexity, due to omitting various functions and ports relating to current common TVs or a simplified remote control and TV menu, as described above. An optimized performance level relates to the performance level that is really needed for an innovation's actual purpose compared with current solutions (Weyrauch and Herstatt, 2016). In the case of the prototype, the TV is adapted mainly to the needs of elderly people, visual- or hearing-impaired people and can also address many wishes of social and ecological sustainable-oriented people. For example, the resolution is aligned to the TV size (and good enough), whereby the remote control is illuminated for better handling by elderly and visual-impaired people. Also, the modularity and associated better repairability address a better performance level (relating to durability) as current TV-solutions. The

third criteria of frugal innovation "substantial cost reduction" means that an innovation has a significant lower purchase price or lower total cost of ownership from a customer's perspective (at least one third and more) compared with current solutions available (Weyrauch and Herstatt, 2016). The students couldn't estimate the purchase price of the developed TV, but it can be anticipated, that a social- and ecological-fair material procurement and production leads to a higher purchase price compared with current TVs, even though some functions and hardware are omitted. Relating to the cost of operation and disposal, the developed TV from the students could save money for the customers, due to up-to-date power saving, durability due repairability and upgradeability, and repurchase of old appliances to the manufacturing company (which will let refurbish and sell them again). The average life cycle of a TV in Germany is approximately five years, whereby 60% of still working flat screen TVs were replaced, because the customers wanted a better one (Prakash et al., 2016). If this aspect can get addressed through the modularity and associated upgradeability, then the developed TV can also have a lower total cost of ownership compared to current TVs.

If a closer look is taken on the topic of sustainability, the following can be noted relating to the developed solution. As the economic aspects can hardly be estimated by the students, the focus lies on social and ecological aspects. The social aspects of the developed TV are based on the evaluated needs of especially the elderly people for self-determination, social integration, and not feeling lonely. These needs get addressed better by the developed solution relating to current TVs, as it is easier to use (remote control, TV menu, front ports, guided or supported initial setup), which should enhance the self-determination of the elderly people and which also leads to a higher possibility of using media libraries or streaming services, which in turn enhances the possibility to find the right entertainment and feeling less lonely. Through the possibility of using media libraries (especially of the German public service broadcaster, which has the programme mandate to deliver comprehensive and balanced information, education, culture, and entertainment) and the zoom function in the remote control (for text overlays in the news) the need of social integration through better information about (social and political) relevant topics gets addressed. In the discussion about the ecological aspects, the focus lies on the four key circular economy principles, described by Levänen et al. (2022): design, reduce, repair and maintenance, and reuse and recycle. The developed TV addresses the design-principle by the aspects of "design for disassembly" and longer durable products through the modular construction as well as considerations relating to the whole product life cycle and "design for the environment" by the means of ecological and social fair material procurement and production, refurbishment, and use of a recycled one-type plastic system for plastic components of the TV. Relating to the reduce-principle the developed TV addresses topics like cleaner (more ecological) production, simplified packaging with recycled cardboard, adjusted to the size of the TV and with minimal printing, and efficient technologies due to up-to-date power saving hardware and software. The repair-and-maintenance-principle gets addressed again through the modularity of the developed solution, which should extend the product lifespan, due to the TV is better repairable and upgradeable, also by the clients, which addresses some

do-it-yourself aspects. The reuse-and-recycle-principle gets mainly addressed by the ideas of upgradeability as well as taking back old TVs (when the clients do not want to upgrade them), remanufacturing them, and selling them as refurbished TVs for a lower price (which opens up the opportunity to sell a more ecological sustainable TV at a lower price and thus, addresses social-economic sustainability).

4.7. Evaluation

The means of the ex-ante and ex-post questionnaires as well as the means of the surveys relating to the third, fourth, and fifth session (marked with a big "S") can be seen in Table I (sample size of nine students). For a more standard presentation of the means, the points and scales got transformed to a scale of ten. No recognizable influences of the various sample aspects (gender, age, course of study, semester of study, or LEGO® building experience) relating to the outcomes were observed, which can be explained, amongst others, by the small sample size of nine participants.

Table 1: Evaluation results

Domain	**Category**	**Mean ex-ante**	**Mean ex-post**	
Cognitive domain (questionnaire)	Knowledge	2,4	6,9	
	Comprehension	0,7	6,2	
	Application	0	4,3	
	Analysis	0,2	3,7	
	Synthesis	0,7	8,5	
	Evaluation	0	5,7	
Affective domain (questionnaire)	Receiving	6,9	7,2	
	Responding	8,7	8,2	
	Valuing	8,7	8,4	
	Organization	social 4,1 ecological 3,8 economic 2,1	social 4,4 ecological 3,8 economic 1,8	
	Characterization	7,8	8,4	
Domain	**Category**	**Mean S 3**	**Mean S 4**	**Mean S 5**
Affective domain (survey)	Receiving	5,3	5,7	7
	Responding	8	5,6	8
	Valuing	4,8	4,9	6,5
	Organization	5	5,2	6,3
	Characterization	5,1	5,2	6,6
Psychomotor domain (survey)	Perception	x	x	x
	Set	6,7	7,6	7,6
	Guided Response	8,2	8	7,8
	Mechanism	7,1	8	7,8
	Complex Overt Response	7,3	7,6	7,1

In session two, only the perception-level of the psychomotor domain (students are building with LEGO® bricks in the warm-up tasks) was observed and rated with 7,1.

No sufficient observations were conducted in the sixth session, because there was not much building with LEGO® bricks relating to the adjustments to the prototype.

The goal of the evaluation was to assess the suitability of the seminar concept to teach sustainable frugal innovation and their development to business students. Relating to the **cognitive domain**, it can be noted, that in all categories a cognitive growth took place relating to the topics of frugal innovation, sustainability, sustainable frugal innovation, and frugal innovation development (in sum sustainable frugal innovation development). Across all six categories the mean results in 5,2 relating to the change from the ex-ante to the ex-post evaluation (with a mean of 0,7 as starting point), so that the students reached in average approximately 60% (mean 5,9 as end point) of the cognitive contents at the end of the seminar. Especially in the description of a new sustainable frugal innovation (category "Synthesis") the students performed well in the ex-post evaluation (in average a growth of 78%).

The first result relating to the **affective domain** belongs to the category "Receiving", in which the awareness of frugal innovation and sustainability, taught in a sixty-minute lecture in the first session (launch event), was measured. The ex-ante value was 2,4 before the lecture (category "Knowledge", cognitive domain) and the ex-ante value after the lecture was 6,9 (category "Receiving", affective domain). So, the lecture provided in average 45% knowledge growth. After the seminar, the value increased only a little to 7,2 (category "Receiving", affective domain, ex-post). Interestingly, this value differs from the value 6,9 of the category "Knowledge" (cognitive domain, ex-post), although the same content was evaluated, only with different wording in the questions. In the next two categories of the affective domain (questionnaire) "Responding" and "Valuing", in which the interest in sustainable frugal innovation development as well as the will to address sustainable issues in the student's daily life and study/working were measured, there was a slightly decline in the mean values (-0,5 by interest in sustainable frugal innovation development and -0,3 by addressing sustainable issues in daily life and study/work), whereby the overall value is still high (8,2 and 8,4). Even if the interest and seeing the worth in sustainability (and frugal innovation) are slightly decreased, there was a slightly increase in prioritization of social aspects (+0,3) over economic ones (-0,3) in frugal innovation development and the internalization of social and ecological values in the student's personalities (+0,6). Across all five categories of the affective domain (questionnaire) there was only a minimal increase of 1% from start (8,0) to the end (8,1) of the seminar. The picture looks different with the survey relating to the affective domain. All values, except one (category "Responding", session four), increased over time, starting with a mean of 5,6 across all five categories in session three and ending with a mean of 6,9 in session five.

Relating to the **psychomotor domain**, which is linked to building with LEGO® bricks (in sustainable frugal innovation development), the students started with an already high mean of 7,1 in the warm-up tasks (category "Perception", session two), which can relate to the fact, that all students built with LEGO® before. The means of the other categories fluctuate over the three relevant sessions. Relating to the category

"Mechanism" (building purposeful LEGO® models) and "Complex Overt Response" (skillfully perform in the LSP-process) the students performed overall well in the seminar (mean of 7,5 over all two categories and three sessions), but with no clear indication that they got better at the end. This also applies to all categories of the psychomotor domain, where the means across all four categories (without "Perception") are high (session three: 7,3, session four: 7,8, and session five: 7,6), but with no clear trend of getting better in the last evaluated session.

4.8. Real use of LSP

Apart from the warm-up tasks for the skills building (technical, metaphoric, and storytelling) in the second session, it was intended to use LSP:

- to build the persona, story map, and problem statement in the third session,
- to generate and model ideas to address various pain points of the concrete object of utility and remodeling the selected solutions by using SCAMPER in session four,
- to build a prototype and realize a product concept in the fifth session, and
- to realize the go-to-market strategy in session six.

At the end, the students used LSP in the second session for building the persona and the problem statement, both first individual based on their own observation interviews and afterwards together with common aspects of their individual models. They did not use LSP for the story map, because they had a fruitful discussion and made meanwhile (digital) sketches about a common story map for their persona (LSP was not needed for a mutual exchange). The students used LSP to model and remodel ideas to address various pain points from elderly people relating to watching TV in the third session but spent more time discussing and (digital) recording the potential solutions. In the fifth session, the students used LSP to build the prototype, considering sustainable aspects, especially circular economy principles, but did not use LSP for realizing the product concept. This was only discussed verbally, but the students used the prototype-model as basis for discussion. The same applies for the realization of the go-to-market strategy in session six (no building with LEGO® but using the prototype-model as basis for discussion).

5. Discussion

5.1. Domains of learning

The developed concept is suitable to teach sustainable frugal innovation development to business students. Based on the evaluation results, the concept is most suitable to address the **cognitive domain**, where the students had in average a growth of approximately 50% over all six categories relating to sustainable frugal innovation development. These 50% were achieved without learning by heart, but with mental skills development and knowledge transfer through the seminar by means of playful

learning (LSP), short presentations of the relevant content, the application of this content in creative ways, and discussion about it.

Whereas the students reached in average approximately 60% of the cognitive contents of the seminar, their **affective outcome** was in average approximately 80% relating to the questionnaire. This percentage was nearly the same at the beginning of the seminar, whereby the more complex feeling-levels of "Organization" (+3%) and "Characterization" (+6%) performed better. The overall result in average at the beginning of 80% is already high, so that there was not much room for an increase. Furthermore, I assume, that the students got a little bit more grounded relating to their assumptions what it needs to live and work in a sustainable manner (-5% relating to interest in sustainable frugal innovation development and -3% relating to address sustainable issues in daily life and study/working) due to the knowledge transfer, their working and discussing during the seminar, and a resulting more realistic assessment by the students relating to these topics. The affective outcome relating to the survey was in average approximately 70% with an increase of approximately 13% from session three to session five. The differences between the affective self-assessment (questionnaire) and the external assessment (survey) of the students relate to the increase and the outcome. The students assess themselves better at the beginning and at the end (without much improvement, 80% to 81%) as the external assessors (56% to 69%). These differences can be justified by the differing self-perception of the students and the perception of the external assessors relating to their emotional dealings in the seminar. The students did not show many emotions at the beginning of the seminar, due to they needed to get used to the sustainable frugal innovation development process and the methods of DT and LSP. Furthermore, they needed some time to get used to the environment (e.g., other students, lecturer, assessor) to build trust and they first needed to develop the cognitive skills relating to sustainable frugal innovation development, before they can valuing, prioritizing, and internalizing relating (social and ecological) aspects. To sum up, the concept addresses also the affective domain with an improvement of 13% in average from an external assessor point of view and high affective outcomes in the self-assessment with 81% (and 69% in the external assessment) at the end of the seminar. The verbal overall evaluation at the end of the seminar also revealed, that some students got more sensitized for the needs of elderly people (e.g., their loneliness and wish for social participation) and now take some more time to talk to them, for example at work (student employment in retail companies).

Relating to the **psychomotor domain** all the students built with LEGO® before and started with an already high percentage of 71% in average in the warm-up tasks (category "Perception", session two), which represents the most simply demand. The fluctuation of the means of the categories "Set" and "Guided Response" over the three relevant sessions can be explained by different building needs in the different sessions, due to sometimes it made no sense to build a LEGO® model and therefore, the students could neither build nor follow instructions from the LSP facilitator. Overall, the students performed well in the seminar relating to the psychomotor domain, also in

the more demanding categories "Mechanism" (building purposeful LEGO® models) with 76% over all three session and "Complex Overt Response" (skillfully perform in the LSP-process) with 73% over all three session, but with no clear indication of an increase or decrease of their performance, which can be explained with already high means at the beginning of the seminar (especially from session three). Although there was no clear improvement of the students relating to the psychomotor domain, seven of nine students chose the seminar because of building with LEGO® bricks. Therefore, LSP can be taken as an incentive to induce the students to engage with topics like sustainability or frugal innovation and I conclude that LSP can support the motivation of students, as described by James (2013, 2019).

5.2. Teaching methods

As shown in the section "2.2 Design Thinking and LEGO® SERIOUS PLAY®" DT and especially LSP are no new concepts in business schools, but they were not used before to teach frugal innovation in general and sustainable frugal innovation development particularly. Main differences can be found in the direction of the innovation processes respectively, the emphasis of the innovations, in our case frugality and sustainability, which results in differing principles and frameworks. **DT** is especially relevant for the development of frugal innovation, due to the customer focus is emphasized in the empathize- and define-phase and highly relevant for the analysis of demanded core functionalities and related performance level of frugal innovation. What is needed at the beginning of the sustainable frugal innovation development is the definition of a frugal and sustainable framework. This means, that a decision is needed, which frugal and sustainable criteria should be applied in the development process, which gets especially important in the ideate- und prototype-phase. Relating to the frugal aspects for example, the essential attributes of frugal innovation (functionality, affordability, usability, aesthetics, robust, performance, and accessibility) of Singh et al. (2020) can be applied.

LSP helped the students in the seminar to model their ideas quickly, present them in a vivid way, and thereby create a base for discussion, which supports joint solution finding. LSP worked best when the students modelled material objects, like a concrete TV or remote control. For less concrete topics like the product concept or the go-to-market strategy, they did not use LSP, although it was intended (by the lecturer) at the beginning of the seminar. On the one hand, these topics are more abstract and modelling them comes not so intuitive, on the other hand, the discussions were fruitful enough, even without a model. Parts of these discussions were also negotiation processes about the direction of the product (relating to sustainable aspects) and modelling meanwhile had slowed down the exchange of views. As the students have good analyzing, reflection, and communication skills, I propose, that they are not so much dependent on LSP as a tool for discussion support. Groups with much fewer of such skills will probably more rely on LSP as support tool. At the end, LSP helped to get a material prototype, which could be evaluated in the test-phase (with pictures of it and a story map for using it), without using resource-intensive technologies and

processes, like injection moulding, CNC machines, or thermoforming. Therefore, LSP can be seen as a frugal way for teaching (sustainable) frugal innovation development.

6. Conclusions

6.1. Implications

In this paper a new concept is presented relating to teaching (sustainable) frugal innovation development in higher education. The teaching content relates to key features of frugal innovation (like core functionalities, cost reduction, and optimal performance level), tools and strategies (like design for disassembly or design for sustainability), and the frugal innovation development process (context and needs analysis, idea generation, concept development, design, prototyping, testing). The concept allows other researchers and lecturers to apply DT and LSP for innovation development (especially for frugal and sustainable ones) in other higher education contexts and institutions. A sensitization for frugality and sustainability in the course of study, for example through a seminar about sustainable frugal innovation, can support the integration of these topics in the later work life of the students.

The concept (without the evaluation parts) can also be used for the sensitization of engineers and managers for the integration of frugal and sustainable aspects in innovation development, for example in in-house seminars or external consulting concepts. Furthermore, I assume, that the concept is also suitable for practical and concrete (sustainable) frugal innovation development in all kinds of organizations, like private companies, public organizations, or Non-Profit Organizations. For a more marketable innovation, it is important to focus even more on the empathize-phase of the DT-process with a higher number of participants to get wider and more detailed costumer insights for correct persona(s). Also, the building of various prototypes, based on different (set of) ideas would be a good idea to get various solutions for testing and thus, a wider range of feedback. How organizations organize the temporal sequence of the concept depends on the availability of customer needs analyses or if the innovation project team (which conduct the concept) must survey themselves. If the needs are already available, the innovation project team can conduct the concept from the second DT-phase “define” to the fourth DT-phase “prototype” in one workshop (maybe in several consecutive days, dependent on the extent). For the testing, the innovation project team or the marketing department (if they are not part of the innovation project team) have to get back to the customers to get feedback on their prototypes and meet again afterwards to rework their solutions together and decide on one.

Within the DT-process, LSP can support especially the generating, modelling, and discussing of persona(s) and problem statement(s) in the define-phase, ideas in the ideate-phase, and prototype(s) in the prototype-phase. Especially, in organizations with fewer resources, for example in developing and emerging economies, LSP (or more general building with clamping bricks) could be used as a frugal way for (sustainable frugal) innovation development. In groups with less skills in analyzing, reflection,

communication, and shortcomings relating to expression of ideas and discussion, LSP can be used also in a wider range of applications, like modelling the story map, business model, product-concept, and go-to-market-strategy. In this case, a proper warm-up-phase and teaching of the relevant (technical, metaphoric, and storytelling) skills is highly relevant to support the transfer of one's ideas in useful models.

6.2. Limitations

The study took place at a German university with Bachelor students and a rather small number of (nine) participants, which limit the significance of the results and evaluation. For a sounder evaluation a bigger sample with more heterogeneous characteristics would be helpful. These could be studies at other (types of) German higher education institutions (other universities, universities of applied sciences, or universities of cooperative education) and higher education institutions in other advanced economies. When testing the concept in other advanced economies, the influence of varying consumer habits (probably differing from the German ones) will be an additional influencing factor to consider. Additionally, more heterogeneous characteristics could also address MBA or Master students and students of other business courses of study, like business mathematics, business informatics, or Entrepreneurship.

High initial levels in the affective and psychomotor domains were also an issue in the study, which could have led to a limited development of the full potential of the concept in the current study. A sample with low levels in the domains would be interesting to study in more detail the effect of the concept.

Despite there was a standardized observational protocol and instructions, the external assessors came sometimes to lightly different assessments of the students relating to the affective and psychomotor domains. To address this issue, another evaluation design could be helpful, for example, to shift from the more qualitative and observational study to a more quantitative and experimental one in a controlled setting (Zenk et al., 2018).

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