Smart Innovation, Systems and Technologies 68

Giampaolo Campana
Robert J. Howlett
Rossi Setchi
Barbara Cimatti *Editors*

Sustainable Design and Manufacturing 2017

Selected papers on Sustainable Design and Manufacturing

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Editors
Giampaolo Campana
Università di Bologna
Bologna
Italy

Robert J. Howlett
Bournemouth University
Poole, Dorset
UK

Rossi Setchi
Cardiff University
Cardiff
UK

Barbara Cimatti
Università di Bologna
Bologna
Italy

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Foreword

For over a decade, the mission of KES International has been to provide a professional community, networking and publication opportunities for all those who work in knowledge-intensive subjects. At KES, we are passionate about the dissemination, transfer, sharing and brokerage of knowledge. The KES community consists of several thousand experts, scientists, academics, engineers, students and practitioners who participate in KES activities.

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It is essential for research groups to communicate the outcomes of their research to those that can make use of them. But academics do not want to run their own conferences. KES has specialist knowledge of how to run a conference to disseminate research results. Or a research project workshop can be run alongside a conference to increase dissemination to an even wider audience.

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KES works in partnership with the Institute of Knowledge Transfer (IKT), the sole accredited body dedicated to supporting and promoting the *knowledge professional*: those individuals involved in innovation, enterprise, and the transfer, sharing and exchange of knowledge. The IKT accredits the quality of innovation and knowledge transfer processes, practices, activities, and training providers, and the professional status of its members.

About KES International

Formed in 2001, KES is an independent worldwide knowledge academy involving about 5000 professionals, engineers, academics, students and managers, operated on a not-for-profit basis, from a base in the UK. A number of universities around the world contribute to its organisation, operation and academic activities. KES International Operations Ltd is a company limited by guarantee that services the KES International organisation.

April 2017 Robert J. Howlett

Preface

Writing a book is always a cooperative work. Even in the case of a sole author, a number of colleagues, collaborators, assistants and often friends and family too are directly or indirectly involved. Writing a book is always a hard job because it requires a deep understanding and a willingness to provide useful information or concepts that will eventually help readers in developing their own projects or give inspiration for new ideas. **Writing a book means sharing ideas and sowing the seeds of new ones.**

Scientific books often gather the work of colleagues based on a specific topic, and this volume collates specifically the accepted papers of the Fourth International Conference on *Sustainable Design and Manufacturing*, SDM 2017. The event was organised and scientifically supervised by the University of Bologna, Italy, in collaboration with KES International, UK. The conference took place in Bologna on the 26–28 April 2017. The papers were submitted to a rigorous peer review before being accepted in order to guarantee the high scientific level of this publication.

The SDM conference is proposed by scientists and academics in collaboration with industrial partners and institutions with the aim of providing an occasion to share knowledge and to discuss and identify new challenges concerning the development and the application of the concept of sustainability, in particular as regards **design and manufacturing**. Industrial production is one of the main engines that drive social welfare and development, employing people and producing goods. The good design and fabrication of any industrial product is then fundamental not only to increase enterprise competitiveness, but also to improve society in general. Nowadays, neither design nor manufacturing can be considered good if they are not sustainable.

The combination between design and manufacturing proposed by this conference is quite unusual as these topics are often discussed in scientific conferences in separate sessions. This old approach considered these two activities sequential, while in the world of today, they are very much integrated and concurrent. This book echoes and embraces this important duality, and readers will find a number of ideas and directions regarding both design and manufacturing.

An **interdisciplinary approach** is necessary in the understanding of sustainability. The three well-known dimensions of sustainability are as follows: environmental, economic and social. Different competences are involved and needed to face sustainable issues and to find new and possible solutions. Any research concerning sustainability involves **different disciplines,** and the importance of **crossing competences** and professions is universally recognised. Scientific events such as the SDM conference, where scholars from different fields and countries can meet and young scientists can experience an interdisciplinary and multidisciplinary surrounding, provide an excellent platform and opportunity for the **cross-fertilisation** of ideas and solutions.

The main topics presented in this volume are as follows: sustainable design, innovation and services; sustainable manufacturing processes and technology; sustainable manufacturing systems and enterprises; decision support for sustainability.

Some articles are also dedicated to the following subjects:

- Business model innovation for sustainable design and manufacturing.
- Resource and energy efficiency for sustainability advances in process industries and business model innovation for sustainable design and manufacturing.
- Sustainability in industrial plant design & management: applications & experiences from practice.
- Sustainability of 3D printing and additive manufacturing.
- Sustainable mobility, solar vehicles and alternative solutions.
- Eco-design through systematic innovation.
- Sustainable materials such as renewable and eco-materials, bio-polymers and composites with natural fibres.
- Sustainable mobility, solar vehicles and alternative solutions.

With the increasing and pressing need for sustainability, the last two topics listed above are becoming ever more important and the attention of the scientific and industrial world towards sustainable materials is growing rapidly. The present challenge in the field of materials science also includes composites, which have introduced important innovation in industrial production but still present limits regarding recycling. At present, they cannot be considered the best solution from the point of view of sustainability, and for this reason, research is intensifying in this field.

Mobility is always an important societal challenge, and our quality of life can only be increased if the adopted solutions are sustainable. Sustainability of solar vehicles and of the numerous technical issues related to them, such as electric batteries and electric engines, is an important field of investigation that has produced relevant advancements.

This volume explores a number of these areas, and many valuable indications and practices are given.

The conference was opened by three significant keynote speakers: **Günther Seliger**, Chair of the GCSM (Global Conference on Sustainable Manufacturing) and Professor at the Department Assembly Technology and Factory Management of the *Technische Universität Berlin;* **I.S. Jawahir**, Director of the Institute for Sustainable Manufacturing at the *University of Kentucky* and Professor of Mechanical Engineering (James F. Hardymon Chair in Manufacturing Systems); **Shahin Rahimifard**, Director of the Centre for Sustainable Manufacturing and Reuse/Recycling Technologies at the *Loughborough University* and Professor of Sustainable Engineering.

The results of their studies have been published in a number of books and scientific papers and represent fundamental scientific literature for any researcher who deals with sustainable design and manufacturing. **Their seeds have been sown in a number of publications and also here**.

We would like to gratefully acknowledge all the researchers who contributed their work to realise this book. We thank the Scientific Committee and its members for their tireless revision of the papers here published and all the colleagues who chaired the sessions of this event. Heartfelt thanks are also extended to the Organising Committee for its fundamental support in making this conference possible, in particular Prof. Robert Howlett, as the Executive Chair of the SDM and as the KES International Executive Chair, and all the KES staff.

A final special thank to Springer, our publisher.

We hope that this conference proceedings book can be a useful publication, providing novel ideas and directions to develop new research concerning the topical issues of sustainability in design and manufacturing.

March 2017

Giampaolo Campana
Barbara Cimatti

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Leverage of Industrial Engineering Education for Sustainable Manufacturing

Pinar Bilge(✉), Soner Emec, and Günther Seliger

Department of Machine Tools and Factory Management,
Technische Universität Berlin, Pascalstrasse 8, 10587 Berlin, Germany
{bilge, emec, seliger}@mf.tu-berlin.de

Abstract. The connected impact of management and technology can considerably contribute to achieve sustainability in global value creation. Industrial engineering started as an educational program at universities based on existing programs in business administration and engineering. The expanding application of this integrative approach of science and practical implementation in industry and in societal communities coins the architecture of how to implement sustainability in different societies. The practical case of setting up a joint program of universities in an early developed and an emerging country illustrates how potentials of industrial engineering can be exploited for promoting sustainable local manufacturing.

Keywords: Sustainable manufacturing · Industrial engineering · Transformative attributes · Engineering education

1 Introduction

A well-educated population is essential for local and global well-being, and sustainable development. Education and intense training play key roles in providing people with the capabilities needed to contribute to the development of sustainability. Industrial engineering (IE) can help demonstrating how sustainable manufacturing (SM) embedded in value creation becomes superior to traditional single paradigms of management and technology [1]. In traditional manufacturing engineering education, the paradigm of faster, more accurate and cheaper drives technological development. Criteria of cost and benefit drive education and practice in economics. Sustainability in its economic, environmental and social dimension is an approach to cope with the challenges of human development on earth with respect to coining wealth by business in fair partnership, by care about natural resources within the limits of their availability and by developing social life in manifold of cultural directions [2].

IE is well-established to be effective in practice and research in manufacturing. Focus on the education and implementation of IE is required to answer the question of how industrial engineers can act as change agents towards sustainability. SM is introduced in Sect. 2 in order to formulate IE objectives within educational frameworks. Section 3 presents how teaching and research in IE can contribute to sustainable value creation by innovative developments in engineering simultaneously using the dynamics of competition and cooperation in the global arena of modern logistics and

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communication [1]. A transformed IE undergraduate program, which is embedded in a newly established engineering school in cooperation between an early developed and an emerging country is presented in Sect. 4. A case integrated into practical components of the program demonstrate the leverage of IE for sustainable development.

2 Review

Potentials of methodologies in engineering and economics are explored for useful applications in industrial value creation in theory and practice. The review and analysis of the current state-of-the-art topics cover sustainable value creation architecture and with its IE attributes of education and practice. Sustainability has become an urgent requirement for both engineering and economics science, considering the limits of resources, growth and the unequal distribution of wealth.

2.1 Sustainable Manufacturing

Engineering is exploiting potentials for useful applications. Manufacturing, as a specific discipline in engineering, starts from human thinking and imagination, from knowledge about natural scientific phenomena, from physical materials and shapes value creation via processes in management and technology, objectified in tangible and intangible products, in physical artefacts and services [1].

Gaps of development between early developed and emerging countries can be closed by applying the approach of help for self-help [3]. Paradigms of manufacturing in historical development and a review of major publications related to SM and its conceptual and constituting elements concludes an architectural framework for value creation, as presented in Fig. 1. Value creation factors as products, processes, equipment, organization and people shaping value creation modules to be valuated according to sustainability impacts are rendered [4]. Perspectives of vertical and horizontal integration are pushed by cooperation and competition. This architecture can be used to model any value creation through SM.

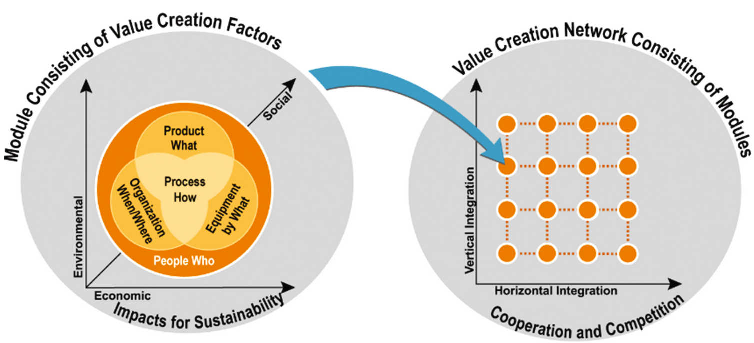

Fig. 1. Value creation architecture [4]

The solution approaches for sustainable development are specified in economic, environmental and social dimensions of value creation. Synergies of management and technology in these solution approaches are obvious:

- Economically, wealth can be achieved in the different areas of human living without increasing physical resource consumption by selling functionality rather than tangible products.
- Environmentally, non-renewable resources must not be disposed anymore but regained in product and material cycles. Chances of substituting them by renewables must be exploited, but only to the extent that renewables can be regained.
- Socially, a global village with less than one billion out of more than seven billion people consuming more than four fifths of global resources is hardly acceptable for living peacefully together. Teaching and learning for a global culture, wealth and health become vital tasks for the global human community [1].

If the lifestyles of upcoming and also developed communities will be shaped in the future by the existing, actually predominating technologies, then the resource consumption will exceed every accountable economic, environmental and social bound. Sustainable engineering represents a new scientific approach to cope with this challenge [1]. SM in its depth of technology in product development, processes and equipment and its breadth of managing human creativity, initiative and entrepreneurship has evolved a powerful leverage for organizing development and realizing physical products and services, business and wealth in the framework of regional and global markets [4]. The potentials of engineering with appropriate capabilities for leveraging SM should be exploited within this frame.

2.2 Industrial Engineering

How to adapt human living to the challenges of sustainability is considerable coined by capabilities provided by higher education. Following the European Qualifications Framework, engineering capabilities describe abilities to perform certain decisions and actions through a set of knowledge, skills and competence in various engineering disciplines [5]. IE provides capabilities to the challenges of SM. It is an area of applied science and professional activity dealing with interrelated technology and management [6]. IE is well-acknowledged with respect to engineering capabilities among others covering soft factors as awareness, motivation, application and transformation [7].

The German National Academy of Science and Engineering (acatech, in German: Deutsche Akademie der Technikwissenschaften) compared numerous courses and attributes of educational programs in IE from early developed countries in 2014 [8].

The comparison focused on identification of traditional IE education, which combines engineering and management education, as presented in Fig. 2. Around 50 curricula with around 40 modules have been analyzed to identify existing attributes by distinguishing the practices among early developed countries. Three attributes are identified as especially relevant for education and training [7]:

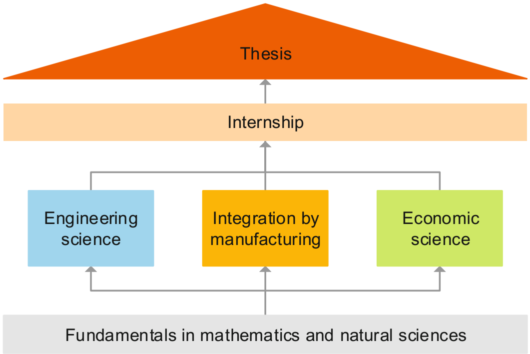

Fig. 2. Framework of traditional industrial engineering programs [8]

- Focus on an interdisciplinary profession that contains two main knowledge domains: technology and management. Interdisciplinary capabilities support engineers to understand conditions and requirements, explore technological and organizational opportunities from different perspectives, while increasing the efficiency of value creation.
- Focus on information and communication technologies, which enable the digitalization of information, data, and facts for many tasks and decisions. Digitalization of information, data, and facts, information technologies (IT) support the development and exploration of educational and practical opportunities to create value through integrated and automated solutions [9].
- Focus on problem-solving, which combines logical thinking with analysis and synthesis by applying methodological knowledge and skills. In IE, problem-solving combines logical thinking with analysis and synthesis by applying methodologies in technology and management [10].

Conflict of goals and challenges for sustainable value creation can be met by integrating different dimensions of evaluation in management and technology [11]. New attributes are needed to logically and sequentially link sustainable value creation to manufacturing.

3 Transformation

Enhancing technology and management both shaping IE by respective education and training provide knowledge, skills and motivation for initiative, creativity and hard work. The architecture of transformative shaping IE is specified as mutual relations between IE and SM [7]. Starting from traditional generic IE framework different attributes directed to competence development in IE for SM are proposed.

Transformative research according to United States National Science Foundation can overcome limits of only economic impacts by integrating environmental and social impacts in shaping manufacturing for sustainable value creation [12]. Transformation here is used as a term, which calls for a need with impactful changes without altering the fundamentals.

3.1 Requirements

Traditional attributes of IE used in practice, research, education and training are valid to create value in manufacturing. The rapid rise of IT has simplified access to information within projects and allowed for focus on interactions among stakeholders, disciplines, and regions. Simultaneously coping with the multiple challenges of SM can be achieved by IE applying transformative attributes for synthesizing solutions based on analysis of practice and research, education and training and embedded in appropriate organizational structures [13]. Discussions in round tables and workshops with different stakeholder groups, as well as interviews with individual scientists, instructors and lecturers, questionnaires with industry experts, alumni, and students, are used to determine new attributes for transformative IE. In addition to the three conventional attributes in IE, three transformative attributes are identified as especially relevant for IE education and training:

- Focus on projects that incorporate problem-solving, interdisciplinary teamwork, and project management, while emphasizing that there is hardly an individual optimal solution to any problem to increase effectiveness [14].
- Focus on sustainable solutions, which balance impacts to improve the current products and services by designing, operating and assessing value creation in manufacturing [7].
- Focus on glocalization, which is a made up word coined from a combination of the words “globalization” and “localization”, which enables global environmental limitations determining the preferences for local actions and decisions [15].

3.2 Transformed Undergraduate Program

Shifting the focus of industrial engineers to SM requires the transformation of educational programs to provide future industrial engineers with the necessary capabilities for SM in terms of technical-methodological knowledge, skills and competence.

Following categories of courses in a transformed educational programs are identified and presented in Fig. 3 [7]: fundamentals in mathematics, natural sciences, engineering, economics, application in technology and management, SM, technical and international internships, soft skills, projects and thesis. All categories together aim to enable closed–loop synthesis by closing gaps of existing and by creating new solutions.

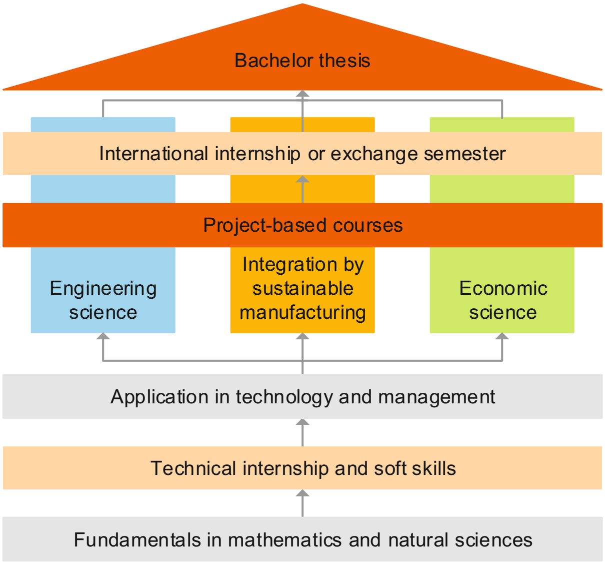

Fig. 3. Framework for transformed industrial engineering program [7]

4 Implementation

Good practices on educational programs in cooperation of early developed and emerging countries demonstrate future perspectives of transformative IE. The framework for transformed IE is exemplarily applied by a case study in education and training.

4.1 Embedding Industrial Engineering Within an Engineering School

A joint undergraduate program on IE with focus on SM is developed by adapting an existing program of an early developed country to the environment of an emerging country, also achieving feedback for improvement of courses. The educational hierarchical structure is adapted to new educational programs within an engineering school based on stakeholder interests [7]. A broader framework is required to embed a transformed IE program for education, implementation, training and research within the new university.

Yearly distribution of practical components involved in a four-year undergraduate degree program support gaining experiences in SM. Technical and international internships can leverage both awareness and motivation in companies and competence with students for sustainable value creation. Goals of the practical components, especially projects with students, regarding the enhancement of engineering capabilities were to

- train students in critical thinking through combining technological solutions and valuating them by addressing principles of SM,

- create empathy in order to increase the ability for recognizing and responding to the needs and requirements of stakeholders within the frame of regional conditions,
- raise awareness for synergies and conflict of goals within the ecosystem in order to improve the value created in local production systems,
- promote innovation and entrepreneurship to engage stakeholders, and
- demonstrate applications with competitive advantages for managerial decisions.

IE students learn and train, are enabled to synthesize solutions for SM, develop their personalities as globally thinking locally acting professionals in SM.

4.2 Sample Case – Energy and Water in Cypriot Agriculture

An undergraduate student team of six students from Germany, four from Cyprus, two from Turkey, one from Spain, and one from India with seven international researchers has executed an eight-weeks project-based course in cooperation of Germany and North Cyprus.

The production of agricultural goods in Cyprus has been mainly hampered by scarce water resources and rising energy prices. Climate changes trigger regulatory and economic counteractions as pumping ground water for irrigation and investment in new, deeper wells, including new filter technologies. Electricity prices for industry in North Cyprus have increased over 250% and annual consumer prices for fuel have increased over 300% in the last decade. Increased prices directly affect farmers, as diesel generators operate water pump systems for irrigating plants over a five-month dry period in summer from May to September. The demand of each farmer is proportional to both harvest quantity and the duration of agricultural activities. To cope with these challenges, modeling precisely the real demand of renewable resources for harvesting as well as access under variable seasonal availability is required [16].

Resource efficiency can be increased by use of regional, low priced and renewable resources for energy generation and water supply, which substitute expensive non-renewable resources. Goals include enabling the access to clean water over dry seasons, protecting of ground water level as well as applying of technologies to reuse the waste. Environmental impacts as CO2 emissions are measured and evaluated.

Despite the current high unemployment rates, the Cypriot workforce, including farmers, has a high level of education. Workshops and meetings with the farmers how to use and share production facilities and generate renewable energy have increased awareness for sustainable value creation. Application–based software can train farmers through simple use of IT tools how to improve the capacity utilization and knowledge share to create synergies. The complete solution concept is presented in Fig. 4 and described in [16]. The hybrid generator encompasses available renewable resources in different combinations that are aligned with the energy demands of the three other value creation modules of production, atmospheric water generation, as well as water and biomass recycling.

As potential solution, the use of biomass, solar, wind, or mixed energy sources are examined to generate electricity for the power grid. Any solution including the

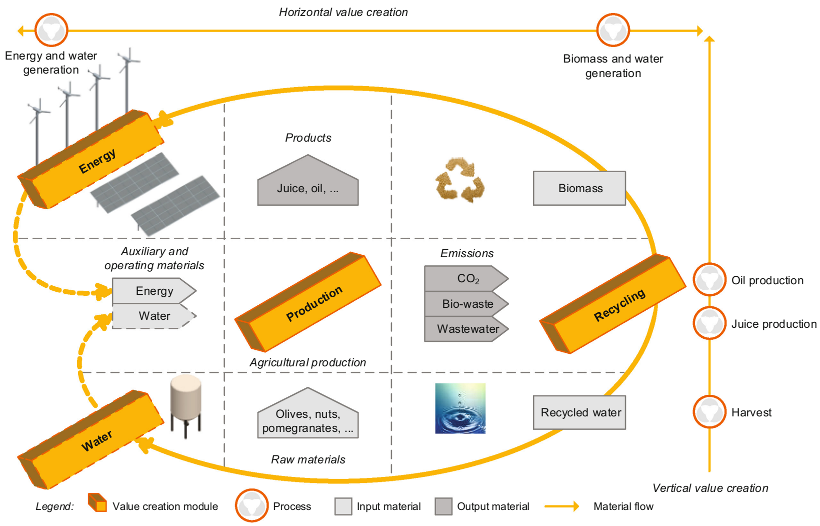

Fig. 4. Solution concept

resources and used technology for energy generation should meet the local requirements, as availability of energy resources, little space, and affordable life–cycle costs, independence of location as well as creating fewer CO_2 emissions, in contrast to currently used solutions. For example, a solution is rated positively if little or no CO_2 is emitted. The return on investment for the implementation of a new energy module is between four and six years depending on configuration and capacity [16].

A hybrid energy generator combines more than one resource to increase the availability of energy supply. It also decreases the energy expenses for the whole system with less operating costs. The hybrid generator consists of two components: clean energy and backup energy source. The clean energy component continuously generates the required energy from renewable resources and organic waste, for example, solar radiation, wind and biomass. The backup component is complemented with a diesel generator and storage batteries.

The score of a solution is built by the multiplied combination of the importance $p(c_k)$ of all categories c_k and its fulfillment $s(c_k(r_i), o_j)$ by a solution o_j. A score $S(o_j)$ presents a summed up score for the jth solution, as presented by Eq. (1):

$$S(o_j) = \sum_{k=1}^{u} \left[s\left(c_k(r_i), o_j\right) * p(c_k) \right] \\ = s\left(c_1(r_i), o_j\right) * p(c_1) + s\left(c_2(r_i), o_j\right) * p(c_2) + \ldots + s\left(c_u(r_i), o_j\right) * p(c_u) \tag{1}$$

The assessment methodology is illustrated for the water and energy module in Table 1. Specific evaluation criteria w_z are defined for each requirement.

This case is interdisciplinary, teamwork-based and project-oriented. Sustainability elements are inter-twinned with fundamentals of engineering science as measurement

Table 1. Evaluation of solutions for the energy module

Requirements		Importance	Solution				
			Diesel generator	Biomass generator	PV solar panel	Wind turbine	Hybrid generator
Productivity	Low area and space	1	3	1	0	0	1
	Low life-cycle costs	3	0	0	9	1	1
Resource efficiency	Temporal distribution of resources	9	9	3	1	3	9
	Low CO_2 emission	9	0	0	3	9	1
	High potential of resources	3	0	3	9	1	9
		Score	84	37	90	114	121

and physical tests, computer aided design, and fundamentals of economics science as business administration, marketing and accounting. Single aspects as assembly technology, energy management are integrated in a sustainable solution.

5 Conclusion

The analysis of IE education and training for contributions to SM maps engineering programs in the qualification framework of knowledge, skills and competences of awareness generation, motivation, application and transformation.

A conceptual framework coined by so-called transformative attributes of IE for implementing SM is presented within the current research. Interdisciplinarity, digitalization, problem-solving as well as focus on projects, sustainable solutions and glocalization are identified as transformative attributes.

A case of sustainability-oriented innovation in an emerging country is presented. Technological and management methodologies are applied to create sustainable local solutions with reference to global criteria of sustainable development. Thus, IE education and training can leverage SM practice.

References

1. Seliger, G.: Sustainability engineering by product-service systems. In: Hesselbach, J., Herrmann, C. (eds.) Glocalized Solutions for Sustainability in Manufacturing. Proceedings of the 18th CIRP International Conference on Life Cycle Engineering, Braunschweig, Germany, May 2–4, pp. 22–28. Springer, Heidelberg (2011)