Zeszyty Naukowe Politechniki Częstochowskiej
Zarządzanie Nr 41 (2021) s. 23-34
dostępne na: http://www.wz.pcz.pl/znwz

DESIGN THINKING IN INNOVATIVE TEACHING IN INDUSTRY 4.0

Agnieszka Ociepa-Kubicka[1], Katarzyna Rozpondek[2], Montalee Sasananan[3], Naritsak Tuntitipawan[4], Nicolae Ionescu[5]

[1] Czestochowa University of Technology, Faculty of Management
[2] Czestochowa University of Technology, Faculty of Management
[3] Thammasat University, Faculty of Engineering
[4] King Mongkut's University of Technology North Bangkok, Faculty of Engineering
[5] Polytechnic University of Bucharest, The Faculty of Engineering and Management of Technological Systems

Abstract: The aim of the article is to present and analyze the design thinking method as an innovative way of teaching on an academic level in the era of the fourth industrial revolution. This method is becoming increasingly more popular. It can be used in both small and large enterprises, for example in the management of innovative projects. A report prepared by the World Economic Forum indicates that the most important skills required of the current and future workforce are analytical thinking and innovativeness. Therefore, higher education institutions should take the responsibility for preparing graduates to design and implement innovations, for example by using the Design Thinking method. The article presents the original assumptions of the Innovative Product Design and Development course prepared as part of the MSIE4.0 project., which is funded within CBHE ERASMUS+ actions. The main objective of the course is to develop the conceptual design of a product with the support of creative thinking techniques and entrepreneurial problem-solving approaches. During the course, the focus is on identifying customers' needs, generating innovative concepts and creating product prototypes.

Keywords: design thinking, higher education, Industry 4.0, innovative product design

DOI: 10.17512/znpcz.2021.1.02

Introduction

Industry 4.0 (I4.0) is currently one of the most discussed topics in the business sector as well as academic and R&D sectors. The overall vision of I4.0 is to join together the most up-to-date technological breakthrough innovations with intelligent, fully automated and AI-driven production systems, which leads to the integration of both the virtual and physical worlds and, as a requirement and a consequence,

[1] Agnieszka Ociepa-Kubicka, PhD, a.ociepa-kubicka@pcz.pl, ORCID: 0000-0002-1736-1844
[2] Katarzyna Rozpondek, PhD, k.rozpondek@pcz.pl, ORCID: 0000-0002-1649-3159
[3] Montalee Sasanana, PhD, e-mail nmontale@engr.tu.ac.th
[4] Naritsak Tuntitipawan, PhD, e-mail supernst88@gmail.com
[5] Nicolae Ionescu, PhD, e-mail ionescu_upb@yahoo.com, ORCID: 0000-0002-8252-0805

ensures more efficient use of information resources. This assumption shows the opportunity to achieve intelligent and flexible production that would enable adaptation to the dynamically changing needs of customers (Zawadzki, Żywicki 2016, p. 105).

I4.0 refers not only to technologies, but also to new ways of working and new roles of employees in the industry. To put it simply, the role of humans in the I4.0 era should be focused on designing, managing and controlling the production process, which should automatically proceed within integrated systems. The specific role of engineers should be underlined here since it is their responsibility to appropriately design and adapt to innovative technologies and solutions, and, in consequence, to create, apply and contribute to new I4.0 business models (*Raport Smart Industry Polska 2019*, p. 8). Due to the dynamic changes resulting from I4.0 advancements in global and national scales, a gap between I4.0 needs, the current requirements of employers as well as the competences and skills of engineers can be observed. This could be directed to newly graduated engineers that are looking for their first jobs, as well as to already experienced and employed engineers (Azmi, Kamin, Noordin 2018, pp. 519-520; *Raport Smart Industry Polska 2019*, p. 11).

According to the World Economic Forum report (*The Future of Jobs Report 2018*, pp. 11-12) the most important skill that is required for current and future I4.0 jobs is analytical thinking and innovativeness. The skills that are expected to gain more importance in 2022 in comparison to 2018 are: an active learning ability and learning strategy, creativity, originality and initiative, as well as proficiency in designing and programing new technologies. Aside from those skills of growing importance, the set of currently appreciated skills with critical thinking, complex problem solving and leadership skills, remains on top (*Table 1*). Identification of the specificity of the demanded skills for I4.0 should indicate the current development path for engineering education development as well as life-long learning opportunities.

Table 1. Top ten most important employee skills in 2018 and 2022

No.	2018	2022
1.	Analytical thinking and innovation	Analytical thinking and innovation
2.	Complex problem solving	Active learning and learning strategies
3.	Critical thinking and analysis	Creativity, originality and initiative
4.	Active learning and learning strategies	Technology design and programming
5.	Creativity, originality and initiative	Critical thinking and analysis
6.	Attention to detail, trustworthiness	Complex problem solving
7.	Emotional intelligence	Leadership and social influence
8.	Reasoning, problem solving and ideation	Emotional intelligence
9.	Leadership and social influence	Reasoning, problem solving and ideation
10.	Coordination and time management	Systems analysis and evaluation

Source: (*The Future of Jobs Report 2018*, p. 12)

According to the abovementioned expectations, the role of the academic sector should be focused on competence-based education of future employees with support of continuous learning, innovation and transdisciplinary cooperation. These assumptions were introduced within the project entitled "Curriculum Development of Master's Degree Program in Industrial Engineering for Thailand Sustainable Smart Industry" (Master of Science i Industrial Engineering 4.0 – MSIE4.0). The implementation of this project should contribute to narrowing the gap between the market expectations and current profiles of graduates, and therefore, to meeting the challenges of the I4.0 development concept (Nitkiewicz, Ayen 2018, p. 1; Nitkiewicz et. al 2019, pp. 661-662). The objective of the paper is to verify whether the method of design thinking, perceived as an innovative way of education, could contribute to the process of reorienting higher education to the new skill set for I4.0 engineers. The paper presents the possible contribution on the basis of an Innovative Product Design and Development course that has been developed within the MSIE4.0 curriculum.

The concept of product innovation

The knowledge-based economy and I4.0 development are prioritizing the activities focusing on innovation, technological breakthroughs and knowledge absorption mechanism improvements. Therefore, the implementation of innovation stimulating solutions, both through public policies as well as educational strategies, could be a source of competitive advantages for industry. Innovation could be defined as a sequence of activities that leads to the production of new and improved products, as well as organizational and technological processes (Szymańska 2017, pp. 694-700). Innovations are classified into product innovation, process innovation, marketing innovation and organizational innovation (OECD / European Communities 2005, pp. 35-49).

The role of product innovation seems to be vital and somehow integrative from the I4.0 perspective. Product innovation could be a result of the autonomous R&D efforts of a company, its cooperation with other business and R&D units, or could be the purchase of a ready-to-use solution in nonmaterial (patent, industrial design or license) or material form (prototype, equipment or machinery). From the perspective of consumers, product innovation is defined through its market perception and its sales numbers (Roehrich 2004, pp. 671-677).

The process of product innovation design and implementation seems to have become an increasingly more complex task nowadays. It is related to the success rate of product innovation and its influencing factors. Chesbrough (2003, pp. 93-135) argues that the success of product innovation is dependent on the rate of satisfying

consumers' needs, but also on its correlation to the product-related absorption capacity of the market. On the other hand, fast paced economic, social, political or environmental changes somehow force the development of product innovation and give it an unprecedented pace. Unfortunately, this challenge for the entrepreneurial sector has many obstacles and barriers, including the high level of bureaucracy in gaining access to external funds, an imperfect education system that does not pay enough attention to the innovation-generating skillset, insufficient cooperation between industry and the academic sector, lack of human resources specialized in launching and implementing innovation processes, lack of complex innovation development programs and clear strategies of implementing them, lack of clarity and long-term stability in innovation-supporting laws and regulations. The role of product innovation in the economy is somehow limited but still, from the company perspective, it is vital to maintain good relationships with customers (Szul 2016, pp. 224-229).

In order to achieve the best possible impact of innovation, with regard to both individual and public perspectives, it is important to introduce activities that would encourage entrepreneurs to undertake product innovation development. The set of such activities should include public support of innovation, a clear and accessible financing system, promotional activities or education. It is quite obvious that higher education plays a key role here by providing courses oriented to product innovation design, assessment and implementation. The saturation of engineering studying programs with product innovation related content should be a priority in innovation-supporting educational strategy. The content should be specific with regard to studying programs and the industries that absorb its graduates. Product innovation related education should include new problem-solving methods, a wide spectrum of product design approaches, consumer-oriented product development and an understanding of market responses to it.

Design thinking – a method of creative problem solving

Design thinking is a method of a systemized approach to the innovation implementation process. The method is focused on deep understanding of consumers' needs. It can contribute to the development of innovative and extraordinary solutions with educational programs, services or products. The method was created at Stanford University in order to transfer academic knowledge to the entrepreneurial environment in the Silicon Valley. One of the authors of the design thinking method is Prof. David M. Kelley. He is the founder of the IDEO design office that is engaged in using the design thinking approach in developing the new products of such companies as Apple, Shimano and General Electric (Educational materials 2017). The

definition of the design thinking approach is not unambiguous in the literature. There are several quite different descriptions and characteristics of the method, i.e. "Searching for a balance between business and arts, structure and chaos, intuition and logic, concept and its implementation, flexibility and formalization or control and empowerment" (Mootee 2013, pp. 26-38).

Design thinking is not a linear or cascade process. It is an iterative process. It can lead through many trials, turns, and returns to a complex solution. The method can be used in a diversity of businesses, including both private and public types. The group of companies that has adopted the design thinking approach is growing and includes, among others, the following examples VOX (furniture), Ergo Hestia (life insurance), Amica (home appliances), Tymbark (fruit and vegetables processing), Kamis (spices), TV "n" (broadcasting service), Allegro (Internet-based retailer), IKEA (home furnishings) or banks. The design thinking process includes several stages (*Table 2*).

Table 2. Stages of design thinking process

Stage	Characteristics
Discovering and defining	Identification, understanding and clear definition of the problem. Overview of the problem from the perspective of consumer experiences and real needs.
Creating	Focus on consumer (real problem and real needs). Generation of multiple potential solutions and designing unique value.
Prototyping and testing	Moving from the idea to the prototype and testing the potential solution. This stage is focused on verifying the proposed value, quickly learning and improving the proposed solution.
Implementation	Preparing the company and consumers to disseminate the innovation through designing the change, communication and indicators enabling assessment of the implementation results and improving the solution.

Source: Authors' own study based on (www.interaction-design.org; Educational materials 2017)

One of the basic assumptions of the design thinking approach is based on focusing on the consumer, which enables full understanding of the underlying needs. Another important issue of the design thinking approach is the engagement of interdisciplinary teams as well as experimenting and testing proposed solutions versus real-life conditions. The specificity of the design thinking approach allows the use of diversified tools at every one of its stages (*Table 3*) (Alves, Nunes 2013, pp. 215-229).

Table 3. Examples of tools used at each stage of design thinking method

Stage	Potential tools
Discovering and defining	value map, interviews (IDI), focus groups, desk research, trends research, mental model, empathy probes, customer journey, service ecology, experience curve
Creating	value proposal, business games, written brainstorming, studio design, design sprint, past-future
Prototyping and testing	storyboard, design sprint, paper prototyping, mockups (lo-fi, hi-fi), models (i.e. 3D printing), customer journey map, service blueprint, storytelling
Implementation	storytelling, communication plans, defining KPIs, scenarios, Sibbet game plan, project chart

Source: Authors' own study based on (www.interaction-design.org; Educational materials 2017)

The solutions and projects that are implemented with the design thinking approach are assessed from three perspectives: available technology, business and the consumer (*Figure 1*).

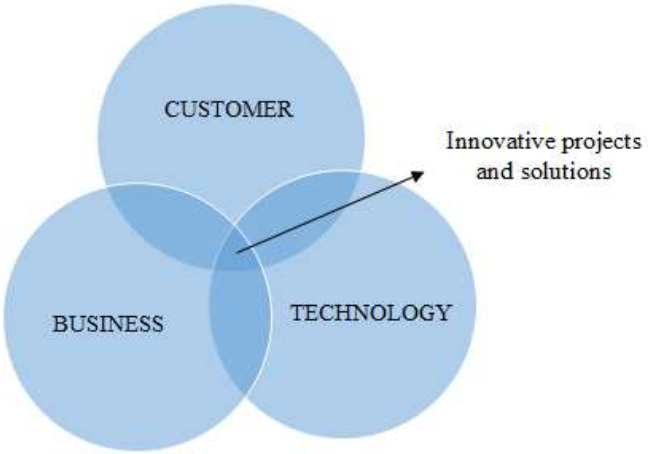

Figure 1. Assessment perspectives for projects and solutions approached with design thinking method

Source: Authors' own study based on (http://dtdlafirm.pl/...)

A common benefit from using the method, as reported by its users, is the increase in consumer satisfaction. It is the result of orienting the design process of products or services to the requirements and needs of consumers. Working within the design

thinking approach could also contribute to an increase in the motivation of design teams, and in turn, would boost the creativity of its members. Another virtue of the design thinking approach is related to its fast-paced prototyping and testing process. Through an encounter with consumers, the possible perception of the product or service on the market is verified, and therefore could benefit in saving resources and time. On the other hand, working within design thinking is difficult, demanding and has some potential pitfalls. It requires the engagement of employees from different fields, regularity in following its stages and a creative approach to any issue that is raised (Chasanidou, Gasparini, Lee 2014, pp. 27-30).

Design thinking is a method that could be used in many different organizations (companies, public administration, universities). Therefore, it is important to disseminate it among key stakeholders. Students, a future key workforce entering the market, belong to one of the most important groups of stakeholders. On one hand, students are not yet routinized by every day working activities. On the other hand, they are able to easily absorb new competences and have an unlimited potential to affect the economic and social reality. It seems that providing an appropriate tool to unleash their creativity, strengthen a practical approach and problem-solving skills is a good idea to make them more impactful in their future positions.

Innovative Product Design and Development course as an example of an answer to the Industry 4.0 challenge by universities

The course of Innovative Product Design and Development (IPDD) was developed within the MSIE4.0 project. Its major focus is on the creative design of product innovation. As its major outcome, the products designed by students should find their application within Industry 4.0 sectors. The main objective of the course is to develop the creative thinking of the graduates and the discussion of issues related to the development and marketing of innovative products, including searching for ideas and creating a concept based on creative thinking techniques and methods of entrepreneurial problem solving, selecting ideas and the development of prototypes, taking into account user needs and the latest scientific research.

The MSIE4.0 project applied backward design to the program and course development. With regard to the high requirements of contemporary higher education, the course development team assumed that the key stage of building the structure of the course was to define its learning outcomes (CLO 1 – CLO 8) (*Table 4*). Learning outcomes are defined as the assets of knowledge, skills and social competences that are acquired by students in the learning process (Kumpas-Lenk, Eisenschmidt, Veispak 2018, p. 180).

Table 4. Assumed course learning outcomes for Innovative Product Design and Development as referred to Bloom's taxonomy levels

Course Learning Outcomes		Level of Bloom taxonomy:
Name:	**Students on completion of this course would be able to:**	
CLO 1	identify the basic concepts related to innovations and the idea of implementing innovative products	Apply
CLO 2	apply the basic techniques of creative thinking and creative problem solving to create innovative product and marketing strategies	Apply
CLO 3	identify the benefits of implementing innovations	Analyze
CLO 4	identify the challenges and opportunities associated with the launch of a new product and propose suitable strategies depending on the product and situation	Analyze
CLO 5	prepare a conceptual product design taking into account user needs and the latest scientific research	Create
CLO 6	valorization, capitalization and protection of original solutions obtained from creative activity	Evaluate
CLO 7	create and co-ordinate cross-disciplinary teams to achieve a common objective	Create
CLO 8	present an entrepreneurial and creative attitude towards seeking various solutions to a problem	Apply

Source: Authors' own study

An appropriate definition of course learning outcomes requires changing the way of thinking with regard to the educational process. Additionally, it requires some proficiency in its supporting tools. One of the tools is Bloom's taxonomy that presents the hierarchy of ever more complex processes that the student should be able to adapt to. Bloom proposed his classification based on the diversification of three learning domains: cognitive, psychomotor and affective. In each one of the domains the hierarchy of complexity levels of learning outcomes was developed. The hierarchy of competencies referring to the cognitive domain includes six major categories of the cognitive process:

- Knowledge
- Comprehension
- Application
- Analysis
- Synthesis
- Evaluation

Knowledge is the lowest, most basic level and above it there are more demanding ones; in the sense of competences the levels build up. Bloom's taxonomy represents the holistic and multilevel character of the learning process. Each one of the levels is affected by the competencies supposedly acquired on the lower levels (Jawor, Szczupaczyński 2011, pp. 76-77).

Working on course and program development in higher education has become a demanding task nowadays, and teachers are required to appropriately design supportive conditions for the learning process and guarantee that students achieve the course learning outcomes. It certainly requires the application of innovative teaching methods that would contribute to the development and verification of higher-level, practice-oriented competences, which are required by Industry 4.0 employers (Koh et al. 2015, pp. 33). Bearing that in mind, we undertook the effort to match and assess the relationship between the course learning outcomes of the IPDD course with the five key competencies that will supposedly be required by employers in the forthcoming years (*The Future of Jobs Report 2018*, pp. 11-12) (*Figure 2*).

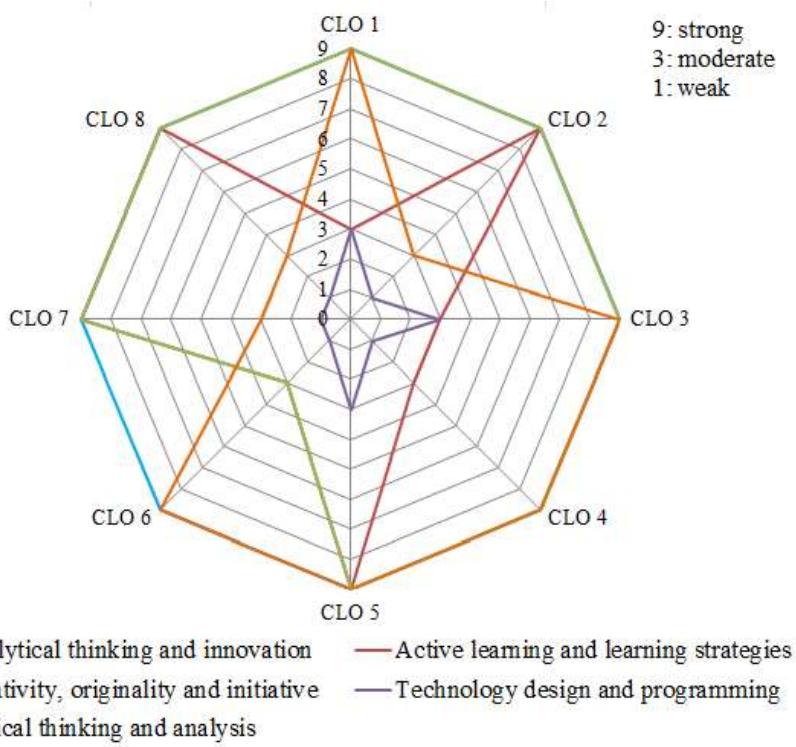

Figure 2. Relationship between IPDD course learning outcomes with key competencies of future employees

Source: Authors' own study

As shown above, the IPDD course learning outcomes show a high level of relationship with 4 out of the 5 top competencies of future employees. Only technology design and programming remain outside the scope of the IPDD course, having a weak or rather moderate relationship level. Since the IPDD course is a part of the MSIE4.0 curriculum, it could be assumed that this specific competence would be achieved through different courses that have more engineering and ICT-oriented profiles.

Conclusions

All over the world we can observe the dynamic process of moving towards a knowledge and data-based economy with the support of modern technologies. The innovation design and application process is one of the most significant factors of economic development. Therefore, research in many different countries is focused on searching for new sources of knowledge and introducing innovative methods that would support the development process of a modern economy. Tracking and implementing innovative solutions is a complex issue and certainly requires streamlined support from the education sector. Setting new educational goals and strategies should be correlated with the development of new technologies and the dynamically changing needs of consumers. The Innovative Product Design and Development (IPDD) course was developed within the MSIE4.0 project. Its major focus is on the creative design of product innovation. As its major outcome, the products designed by students should find their application within Industry 4.0 sectors.

In the proposed course, the assumption is made that students after finishing it should be familiarized with basic creative thinking and problem-solving techniques that would provide them with the necessary skillset to create product innovation and marketing strategies, identify the challenges and opportunities related to innovation implementation and the market reaction to it. Graduates should be capable of preparing a product design concept that takes into account the needs of consumers and is aligned to the technology development level within the field. Students should gain analytical skills and the ability to use them in practice, especially within the participation and coordination of interdisciplinary project teams. More attention should be paid to teaching methods that would support the development of those analytical skills and creative thinking competencies. One of such methods is certainly design thinking that stimulates different competencies and provides a perfect training ground to test them. The dissemination of the design thinking approach could significantly contribute to improvement of the role of higher education in the process of making the Industry 4.0 vision come true.

Acknowledgements

This publication is a partial outcome of the project "Curriculum Development of Master's Degree Program in Industrial Engineering for Thailand Sustainable Smart Industry (MSIE4.0)" that has been funded with support from the European Commission (Project Number: 586137-EPP-1-2017-1-TH-EPPKA2-CBHE-JP).

Disclaimer

This publication reflects the views only of the authors, and the Commission cannot be held responsible for any use which may be made of the information contained therein.

References

1. Alves R., Nunes N.J. (2013), *Towards a Taxonomy of Service Design Methods and Tools*, [in:] Falcão e Cunha J., Snene M., Nóvoa H. (eds.), *Exploring Services Science. Lecture Notes in Business Information Processing*, Springer, Berlin, Heidelberg.
2. Azmi A.N., Kamin Y., Noordin M.K. (2018), *Competencies of Engineering Graduates: What Are the Employer's Expectations?*, "International Journal of Engineering & Technology", Vol. 2(29).
3. Chasanidou D., Gasparini A., Lee E. (2014), *Design Thinking Methods and Tools for Innovation in Multidisciplinary Teams*, [in:] Marcus A. (eds.), *Design, User Experience, and Usability: Design Discourse*, Lecture Notes in Computer Science, Vol. 9186, Springer, Cham.
4. Chesbrough H.W. (2003), *Open Innovation. The New Imperative for Creating and Profiting from Technology*, Harvard Business School Press, Boston.
5. Educational materials (2017), *Design Thinking w biznesie*, Warszawa.
6. http://dtdlafirm.pl/podstawy-design-thinking/ (accessed: 12.07.2019).
7. Jawor A., Szczupaczyński J. (2011), *Efekty kształcenia jako centralna idea Krajowych Ram Kwalifikacji*, "Przegląd Socjologiczny", nr 60(4).
8. Koh J.H.L., Chai C.S., Wong B., Hong H.Y. (2015), *Design Thinking for Education. Conceptions and Applications in Teaching and Learning*, Springer, Singapore.
9. Kumpas-Lenk K., Eisenschmidt E., Veispak A. (2018), *Does the Design of Learning Outcomes Matter from Students' Perspective?*, "Studies in Educational Evaluation", Vol. 59.
10. Mootee I. (2013), *Design Thinking for Strategic Innovation: What They Can't Teach You at Business or Design School*, Wiley, Canada.
11. Nitkiewicz T., Ayen Z. (2018), *Identifying Key Criteria in Development of Industrial Engineering Education*, https://www.matec-conferences.org (accessed: 24.06.2019).

12. Nitkiewicz T., Ayutthaya D.H.N., Koomsap P., Lima R.M., Chattinnawat W. (2019), *The Quality of Education on Workplace Safety Master Studies – The Issue of Teaching Methods*, [in:] Ulewicz R., Nikolić R.R. (red.), *System Safety: Human – Technical Facility – Environment*, Sciendo, Warszawa.
13. OECD / European Communities (2005), *Oslo Manual: Guidelines for Collecting and Interpreting Innovation Data*, Warszawa.
14. *Raport Smart Industry Polska 2018* (2018), Ministerstwo Przedsiębiorczości i Technologii / Siemens, Warszawa.
15. *Raport Smart Industry Polska 2019* (2019), Ministerstwo Przedsiębiorczości i Technologii / Siemens, Warszawa.
16. Roehrich G. (2004), *Consumer Innovativeness. Concepts and Measurements*, "Journal of Business Research", Vol. 57.
17. Szul E. (2016), *Konsumenci wobec innowacyjnych produktów*, "Nierówności Społeczne a Wzrost Gospodarczy", nr 46(2).
18. Szymańska E. (2017), *User-Driven Innovation – the Concept and Research*, "Results Procedia Engineering", Vol. 182(6).
19. *The Future of Jobs Report* (2018), World Economic Forum, Switzerland.
20. www.interaction-design.org (accessed: 10.07.2019).
21. Zawadzki P., Żywicki K. (2016), *Smart Product Design and Production Control for Effective Mass Customization in the Industry 4.0 Concept*, "Management and Production Engineering Review", Vol. 7(3).

DESIGN THINKING W INNOWACYJNYM NAUCZANIU W DOBIE PRZEMYSŁU 4.0

Streszczenie: Celem artykułu jest przedstawienie i analiza metody Design Thinking jako sposobu innowacyjnego nauczania na uczelniach wyższych w dobie czwartej rewolucji przemysłowej. Metoda ta jest coraz bardziej popularna. Wykorzystywana może być zarówno w małych, jak i dużych przedsiębiorstwach m.in. przy zarządzaniu innowacyjnymi projektami. Raport opracowany przez World Economic Forum wskazuje, że najważniejszą umiejętnością wymaganą od aktualnych lub przyszłych pracowników jest analityczne myślenie oraz innowacyjność. Dlatego tak istotna jest edukacja na uczelniach wyższych z zakresu wdrażania i projektowania innowacji m.in. przy pomocy metody Design Thinking. W artykule zostały zaprezentowane autorskie założenia kursu Innovative Product Design and Development przygotowanego w ramach projektu MSIE4.0. Głównym celem kursu jest opracowanie koncepcyjnego projektu produktu w oparciu o techniki kreatywnego myślenia i sposoby przedsiębiorczego rozwiązywania problemów. W trakcie realizacji kursu nacisk został położony na identyfikację potrzeb użytkowników, generowanie nowatorskich koncepcji i tworzenie prototypów produktu.

Słowa kluczowe: Design Thinking, szkolnictwo wyższe, Przemysł 4.0, innowacyjne podejścia w projektowaniu