

Developing the Competences of Future Waste Management Engineers

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ABSTRACT

In the automated world of business, a modern engineer should be characterized by a passion for technology, creativity, innovative capacity, initiative and commitment to scientific and technical progress, ease of adaptation, but also conviction about the mission of technology. Among these, a lack of competence in recognition of, and response to, anthropogenic ecological threats and destruction of biodiversity and ecosystems was noticed. The aim of this article was to draw attention to the problems of educating engineers, to include provision with specialist knowledge and development of necessary competences. The article also refers to the growth of waste production, including packaging waste, presenting an example of the use of activating methods in adult education, deployed in the subject “Waste management” for students of “Renewable energy sources and waste management”, implemented at the University of Rzeszów. Such teaching activity is of great importance in shaping the aforementioned competences.

Keywords: engineer, competences, waste management, education, activating methods, packaging waste

INTRODUCTION

In an increasingly automated business world, rapid economic, technological and social changes are taking place. What actions should be taken to keep up with these changes and find oneself in the constantly changing reality? This is a difficult and complex question. Jérémy Lamri [2021] attributes a key role in this respect to the development of new competences: creativity, communication, critical thinking and cooperation. The skills that guarantee professional success in the 21st century are therefore significantly different from those that were in demand not so long ago. While the professionals of the 20th century used the so-called routine and repetitive competences that can be performed by robots in the future, the last two decades have shown that the demand for interaction and analytical skills has increased. Employers now value the people who can learn and adapt to new roles in the organization, who are creative

and show initiative. In the face of the speed and variety of information, in order to achieve above-average results, we should also learn effective communication and efficient teamwork. These soft skills are often underestimated by both students and academic teachers creating engineering study programs.

Considering the challenges faced by enterprises of the 21st century, one cannot forget about educating appropriate staff, especially engineers of Polish technical universities together with entrepreneurs should develop an education system that will ensure the appropriate, desirable structure of qualifications on the market of engineering graduates. Although the waste management sector is developing dynamically, the profession of a waste management engineer is still not listed in the glossary of the classification of occupations and specialties of the Central Statistical Office [<https://stat.gov.pl/Klastacjajae/doc/kzs/slownik.html>]. There are several professions that do not require higher education, such as those of

a waste management technician, waste collection worker, municipal waste sorter, hazardous waste processing equipment operator or municipal waste incineration plant operator. Currently, the profession requiring engineering competences listed in the document of the Central Statistical Office is an environmental engineering engineer – urban cleaning and waste management or an engineer of radioactive waste management. The profession of a waste management engineer has great prospects for employment and operation, because the functioning of the entire waste management sector is currently very important for the comfort and safety of people's lives. Therefore, waste management in the 21st century is characterized by a significant development potential. In 2020, sales in this sector in Poland exceeded PLN 32 billion, which accounted for 2% of GDP and, compared to 2005, meant a five-fold increase. There are 9,000 companies registered in this sector, employing 80,000 people [Portal komunalny.pl, 2022]. Due to the development of circular economy, the demand for new enterprises in this industry with the use of innovative technologies and the generation of new jobs will continue to grow.

Due to progressing globalization and dynamic growth of the population, which, according to UN analysts, in mid-November 2022 has already exceeded 8 billion citizens of the planet [United Nations, 2022], the mass of waste generated by people is growing rapidly. Population growth also increases the environmental impact of economic development, but it is the constant need to increase per capita income, as measured by GDP, that is the main reason for the unsustainable patterns of production and consumption in the world

today [Hickel, 2022]. It is these patterns that are currently causing the degradation of the natural environment and biodiversity. Anthropogenic degradation has taken on such a scale that there is talk of the Anthropocene epoch and ecocide, i.e., ecological suicide due to the approaching final phase of total destruction of the natural environment (killing all life) in a given area, as a result of human activity [Higgins et al., 2013; Mehra et al., 2019]. Waste is one factor of anthropogenic environmental destruction.

According to the definition contained in the Waste Act, waste is a substance or object which the holder disposes of, intends to dispose of or is obliged to dispose of [KPGO 2028]. Packaging waste has been separated from municipal waste because it is generated in households or comes from other waste producers, but due to its nature and composition, it is similar to household waste [Dz. U. 2022, item 699; Tomic et al., 2022]. Packaging is a product, including a non-returnable product, made of any material, intended for storage, protection, transport, delivery or presentation of the products. Packaging includes unit packaging, i.e., packaging that is used to deliver the product to the user at the point of purchase, collective packaging containing a multiple of unit packaging of products, regardless of whether they are handed over to the user or used to supply points of sale, and transport packaging that is used to transport products in unit or collective packaging to prevent damage to products [Dz. U. 2013 item 888]. Packaging may consist of one type of material or, more often, of several layers of different materials, which cannot be separated by hand, and which usually form an

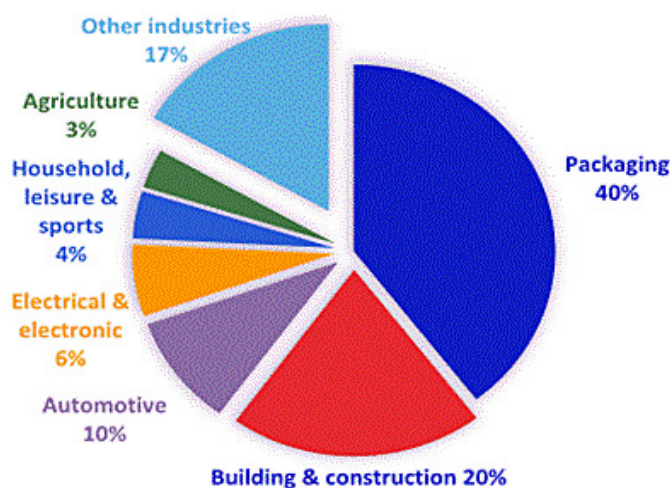


Figure 1. Segments on plastic consumption (Plastic Europe 2020)

integral whole consisting of an inner container and an outer casing and constitute the so-called multi-material packaging [Dz. U. 2013 item 888; Piontek and Jarzębowski, 2015]. Research shows that in 2019, over 83% of waste generated in the European Union was plastic, including as much as 40% of packaging waste (Fig. 1).

The role and size of the waste management sector and the demand for engineers in this industry are therefore very large and will increase in connection with the tightening of environmental policy in the EU, as a result of the aforementioned return to the circular economy model.

In this article, the competences important in educating a modern 21st-century engineer (including waste management engineers) were considered. Among the engineering competences, a lack of recognition and response to ecological threats was noted. The aim of the article was likewise to draw attention to the growing amount of waste produced, including packaging waste. Therefore, the study also described an example of the use of activating methods in adult education, deployed in the subject “Waste management” for students of “Renewable energy sources and waste management”, implemented at the University of Rzeszów. Such teaching activity is thought to be effective and important in shaping the aforementioned competences.

METHODOLOGY

The work was based on a review of the literature on waste, including packaging waste, and on our own experience gained during many years of educational activities with students of the University of Rzeszów. An exercise of searching for the most pro-environmental / sustainable packaging is carried out as part of the “Waste management” course in the “Renewable energy sources and waste management” major. It was tested in three consecutive cycles of education.

RESULTS

Packaging waste against the background of waste management

It has long been known that prosperity has its price. However, it is not only about the price we pay in the store for a given product, it is also the

price of a negative impact on the environment, including the health and life of consumers. When going through life with excess of things that we buy, use and throw away, we often do not find time to reflect on the real cost of using a specific product [Goleman, 2009]. Consumption is currently one of the most important elements of any economy, but it is the tendency to excessive materialism that is becoming a common and dangerous phenomenon for the environment today, because it contributes to the generation of large amounts of waste [Merta-Korzniakow 2018]. The development of humanity in the era of online shopping is intensified by the increase in the amount of packaging waste generated. Online shopping is convenient, but it causes an increase in the production of additional packaging waste, such as cartons and buffering materials, the use of which is dictated by the need to protect products during transport. Recent research reports that online shopping generates 4.8 times more packaging than traditional shopping for the same amount of consumer spending [Kim et al., 2022]. Another source of packaging waste, the amount of which is growing exponentially nowadays, is waste from the food delivery industry, i.e., takeaway packaging waste generation [Li et al., 2022]. The growing mountain of this type of waste is associated with lifestyle changes and the popularity of food delivery services around the world [Hirschberg et al., 2016]. With the increase in urbanization and the acceleration of the pace of work, online food delivery has increased the demand for large quantities of single-use packaging, often made of plastic [Li et al., 2020]. The results of research conducted in China indicate the relationship between the amount of packaging waste of this type produced and night work, the level of GDP per capita, urbanization, population density and the range of the Internet. In addition to the deepening consumerism, the increase in the amount of waste produced, including packaging waste, may be intensified by emergency situations. An example is the COVID-19 pandemic, which has significantly contributed to changing the functioning of the entire world. The emergence and spread of the SARS-Co-V-2 virus resulted in a rapid increase in the production of waste and problems with its handling [Królikowski and Fiedur, 2021], as well as an increase in plastic waste, including the waste constituting used disposable food packaging [Li et al., 2022].

The choice of the items we buy is dictated by various motivations. For some it is the price or quality of the product, for others it is the importance to live in harmony with the environment and in so-called environmental health creating a new consciousness, which is the most important collective effort to protect the planet and the organisms that inhabit it. Therefore, according to ecological intelligence, waste prevention is the basis of the waste management hierarchy [Goleman, 2009]. In addition, with the exponential growth in the amount of waste generated around the world, the next step in the waste management process is recycling or other recovery processes where waste is reprocessed into products, materials or substances for the original or other purposes. Only the elements that cannot be ultimately recovered should be disposed of [Dz. U. 2022, item 699].

In the management of the waste management sector, the possibility of using appropriate techniques and technologies plays a very important role. Appropriate logistics, as well as the current and future long-term strategy that will be able to rely on appropriate, i.e., saving and restoring resources and ecosystems, technological solutions are also important.

Competences of the future profession of a waste management engineer

According to “Przegląd Techniczny” [http://www.pracuj.pl/praca-przemysl-artykuly_11669.htm#top], the ideal engineer is characterized by: passion for technology, creativity, innovative skills, initiative and commitment to scientific and technical progress, ease of adaptation, ability to self-improvement, ability to use computer techniques in everyday work, professional knowledge

and skills, knowledge of foreign languages, management and leadership skills, adherence to the principles of engineering ethics, belief in the civilizational mission of technology. What, for example, does this enigmatic latter theorem mean? Does it raise the awareness of the need to save natural resources, ecosystems and biodiversity? Does it bring to mind the need to care for biodiversity? Does it open one’s eyes to consider the conditions of safe human life on the planet and dispell the myth of growth economics, as an unscientific and very irresponsible gamble in which human life is at stake... [Hickel, 2021]? This issue is currently being considered by many authors. Tobór-Osadnik and Wyganowska [2016] present, for example, the results of research conducted in a group of students of the Silesian University of Technology and employers, concerning their perception of the current education system in terms of shaping the features of an ideal 21st-century engineer (Table 1).

When analyzing the results of these surveys, it can be concluded that, in the opinion of students, professional knowledge is ranked at a high second position, just after creativity (Tab. 1), but general personal skills, such as computer skills, knowledge of foreign languages and passion for technology, are considered as much less important. At the same time, a very low assessment of work ethics and the mission of technology in the modern world should be noted. For this reason, there is a fear that such an attitude may have a negative impact on engineering decisions that take into account the good of society and the environment. It could also be emphasized here that the anthropogenic pressure, which is deepening year by year, results from the environmental indifference of the decision-makers, who were previously university students. The sensitivity

Table 1. Results of surveys on desirable features of an engineer, conducted among students of the Silesian University of Technology and employers

A desirable trait for an engineer	
According to students of the Silesian University of Technology *	creativity, professional knowledge, professional skills, ability to innovate, ability to self-improve, passion for technology, ease of adaptation, management skills, initiative and commitment to scientific and technical progress, computer skills, ethical engineering behavior, knowledge of foreign languages, conviction about the mission techniques
According to employers **	responsibility, ability to work in a team, discipline, communicativeness, diligence, creativity, intelligence, accuracy, conscientiousness, education (qualifications), independence, ease of conflict resolution, punctuality, competence, resistance to stress, anticipation, good manners, regularity, credibility, compliance with OHS, availability, firmness, compromise, self-criticism, no criminal record, modesty, alcohol abstinence

Note: * ranking from the most important feature; ** ranking from the highest rank of the trait based on Tobór-Osadnik and Wyganowska (2016)

of students of different faculties to environmental issues differs (it increases with contact with environmental knowledge), as shown in studies of Kostecka et al. [2019]. On the other hand, the results of surveys conducted among employers show that responsibility and the ability to work in a team are the most desirable features of a future employee (Table 1).

The students and employers surveyed by To-bór-Osadnik and Wyganowska [2016] (Table 1) lacked the competence to recognize, prevent and respond to ecological threats among the valued features of an engineer. According to the cited studies, no one emphasizes the need to adjust the attitude, knowledge, skills and competences to the natural sensitivity of all citizens of the currently ailing the Planet.

Meanwhile, do we wonder that only up to a certain time technical progress has been more conducive to the evolution of humanity, creating increasingly better conditions for people's improvement and for an increase in the chance of survival, and from a certain moment this is no longer the case? One may have the impression that a radical change in the role of technological progress took place in the second half of the twentieth century, from the beginning of the Anthropocene. Man began to interfere incredibly intensively and quickly with the natural and social environment. Since then, in the natural sciences, humanities and technical sciences, more and more discoveries and inventions have been used for the purposes that threaten Man. Professor Sztumski [after Górski, 2021] primarily means the discoveries in the fields of nuclear physics, molecular genetics, bacteriology, virology, food chemistry, nanotechnology, electronics, computer engineering, computer science,

artificial intelligence, econometrics and social psychology. Most of them are currently used for military purposes and food poisoning, environmental degradation, biodegradation of the human species as well as enslaving and dumbing down the masses. This predominance of the ill effects of technical progress fueled by scientific progress not only persists but is increasing. However, it should not be concluded that the good effects of technological progress have disappeared.

A very broad analogy could be seen here for the complex phenomenon of the production, use and disposal of packaging and the impact of this system on the broadly understood environment. As scientists [WWF, 2022] inform us in many reports on the state of the planet, we need to set a limit for the acceptable annual consumption of resources and waste production... on December 7-19, 2022, the UN conference on biodiversity (COP 15) started in Montreal. Its goal was to negotiate an international agreement that will allow at least 30% of the land and ocean area to be preserved for wildlife.

The current text is therefore part of the description of the complex conditions for the success of these plans.

Exercise "environmentally friendly packaging" – a proposal for the course of the classes

In the syllabus of the Waste management course implemented in the field of study "Renewable energy sources and waste management", there is an exercise "environmentally friendly packaging". The aim of the classes is to draw students' attention to the problem of the growing amount of packaging waste and the need to

Table 2. The course of the "environmentally friendly packaging" exercise

Stages of the course of the exercise		The name of the method used
1.	Systematization of knowledge on packaging waste	brainstorm
2.	Drawing attention to the problem of the growing amount of packaging waste and determining the causes of this phenomenon	fish skeleton
3.	Presentation of examples of various types of packaging with emphasis on their advantages and disadvantages relevant to the principles of sustainable development	talk/presentation with problem questions
4.	Selection of packaging, taking into account such features as: product safety and appropriately convenient access to the content, packaging functionality, environmental and economic costs of its production, ease of transport of products, reusability of packaging components, impact of waste on the environment, arousing positive emotions	group work, bee swarm, mind map
5.	Presentation of the results of work in the group forum	the presentation
6.	Class evaluation	written report

introduce changes in the design and production of packaging, which is related to the model of responsible and sustainable waste management connected with sustainable consumption. The implementation of the described topic with the use of activating methods proceeded according to the following scheme (Table 2).

Modern and effective education means “not better, but different”. According to this idea, such education should be based on four pillars of teaching and upbringing: learning to know (knowledge), learning to act (skills), learning to be (system of values and attitudes), and learning to live together with others [Robinson, 2020]. In addition, modern education should develop competences such as innovation, creativity, the

ability to solve complex problems in a creative way, make decisions, manage people and coordinate their activities, as well as develop pro-environmental attitudes and behaviors. The use of activating methods in the didactic process helps to increase the efficiency of transferring and acquiring knowledge develops skills and raises competences. In addition, it makes the content more attractive and increases the effectiveness of teaching not only children and youth, but also adults [Turekova et al., 2020]. Suggestions of methods used during the implementation of classes on the described issue are described below (Table 3).

For consideration, the following traditional and innovative packaging is offered to students:

Table 3. Description of selected activation methods [Brudnik et al., 2011; Kupisiewicz, 2012]

Method name	Method description
Brainstorm	It consists in gathering as many ideas and associations as possible in a short time in order to solve a specific password or problem. Using this method develops mental skills, creativity and personal interests of students, it also overcomes resistance to presenting one's own ideas and stimulates imagination.
Fish skeleton (cause and effect diagram)	It consists in drawing a “fish diagram”, entering the main problem in the place of the “head” and determining the main factors written on the “big bones”, which may be responsible for the problem by means of “brainstorming”. Then, students look for reasons that affect a given factor and write them on the “small bones”. The next step is to develop an action plan to solve the defined problem. The described method is used to find the causes of a given problem and to plan actions to solve it.
Talk/presentation with problem questions	It is a conversation with students led by the teacher, as a result of which the group is led to the correct solution to a given problem.
A swarm of bees	The beginning of the work is the division of the group into several teams. Then, students carry out the task of developing a specific task. After the time has elapsed, the leader, with the help of other group members, presents the results of the work in the forum. It is a method that develops the ability to communicate effectively in various situations, present one's own point of view, prepare for public speeches, teaches effective teamwork, and makes individual and group decisions.
Mind map/ Association map	The course of action begins with writing the main entry in the middle of the board and gradually adding all associations reaching the main entry. This method helps to activate students' knowledge, stimulate their fantasy and imagination, and also allows for a subjective ordering of knowledge, corresponding to the logic and method of teaching each student.

Table 4. Report proposal

1. Title page	- names and surnames of the authors - name of the subject, field of study, etc. - SELECTED PACKAGING
2. Contents	
3. Abstract	- presentation of the most important content
4. Introduction	- description of the problem - objectives of the exercise - justification for the choice of PACKAGING?
5. Main part	- a detailed description of the SELECTED packaging - description of the effects that HIS PRESENCE ON THE MARKET will bring on the ecological, social and economic level (pluses and minuses) - comparison to traditional packaging
6. Summary	- a description of how to popularize the use of environmentally friendly packaging with elements of its costs
7. Bibliography	- alphabetical list of publications

1. Egg packaging made of cellulose with the addition of seeds, e.g., grass in the bottom, no stickers, printed with environmentally friendly paint.
2. Water bottle made of stainless steel.
3. Collective packaging of cups made of recycled egg box material.
4. Cabbage leaves – used to wrap portions of vegetables to replace plastic films.
5. Paper box.
6. Glass bottle.
7. Box made of plastic.
8. A tea package made of thinly pressed sugar, a cube with sugar walls containing a portion of tea to be brewed.
9. Multi-material packaging.
10. Wax wraps for storing sandwiches.
11. Biodegradable bags made of corn.
12. Packaging for nuts and dried fruits made of coconut shell.

The packaging most often chosen by students to analyze the effects of their presence on the market corresponded to glass bottles and cabbage leaves replacing plastic foil. Students summarize their ideas in a written statement in the form of an exercise report (Table 4).

DISCUSSION

According to Dehaene [2021], the unique talent of our species is learning. According to him, we are no longer *Homo sapiens* but *Homo docens*, i.e., a species that teaches itself, and it is learning that consists in shaping the internal model of the world [Dehaene, 2021]. It should be emphasized that learning is not the same as memorizing. It is an active process of giving meanings. Only the information that has been ordered is stored in long-term memory and can be used in various situations, because, as Petty [2010] emphasizes, the ordering process takes place during action, not listening. According to the learning scheme, we remember 10% of what we read, 20% of what we hear, 30% of what we see, 50% of what we hear and see, 70% of what we say and as much as 90% of what we do it ourselves [Brudnik et al., 2011]. Short-term memory stores the information acquired through the senses, such as hearing and sight. Therefore, after a while of storage, almost all of them are forgotten. The information transferred to long-term memory is processed and

organized [Petty, 2010]. In addition, the natural potential of the brain, which learns most effectively through actions and experience, should be used in the learning process [Sikorski, 2015]. Therefore, students taught with activating methods start to be independent, develop their own learning strategies, trigger genuine motivation and curiosity to learn, build their own autonomy at work and study [Brudnik et al., 2011].

Spitzer [2012] draws attention to a common problem at universities, i.e., the need to study only for exams. Very often, students, despite the fact that they study something that they have chosen for themselves and what they will then do professionally, often rework the material in such a way that after it is verified with a grade, it is forgotten. In addition, our way of exams teaches not to study in a systematic way. More and more brains are taking advantage of universities. Universities are workshops where neurons are refined, owing to which our brain circuits acquire the highest qualifications [Dehaene, 2021]. Therefore, the introduction of activating methods during classes allows for more effective assimilation of new knowledge using the teaching-by-doing approach. Activating methods used during classes help to arouse students' interest, facilitate the assimilation of new knowledge, help develop one's own ideas, and allow for free communication and discussion on various topics [Brudnik et al., 2011]. Therefore, the methods of active education in the field of broadly understood sustainable development have been successfully used for many years in teaching adults at the University of Rzeszów [Kostecka and Mazur-Pączka, 2015; Mazur-Pączka et al., 2016; Kostecka et al., 2018; Kostecka et al., 2022].

The use of methods that activate the participants of the teaching process helps not only the students but also facilitates the work of the teacher. Admittedly, a teacher who decides to work according to the selected method must prepare materials in advance and arrange the place of study accordingly, but owing to this, he deeply develops his competence in the field of teaching methodology of the subject [Brudnik et al., 2011].

There are many problems and challenges faced by modern engineers; and as can be seen from the current considerations, some of them are challenges that have not yet been realized. In the education of students of technical universities, among the activities aimed at improving and developing the knowledge and

competences of future professionally active engineers, Kaźmierczak [2016] states the need to broadly supplement the content of education at technical universities with non-technical issues and – on the basis of reciprocity – to take into account the problems of technology in educating students at non-technical majors. This seems to be necessary in the perspective of a holistic perception of man in the 21st century and taking the necessary actions to improve and modify the systems of preparation for the implementation of engineering tasks.

According to an encyclopedia definition [Wikipedia.org], an engineer is “a person who has skills and knowledge acquired in the field of engineering and technical sciences”. It is also a term for the professional title awarded by universities after graduation from engineering studies. The above-mentioned author [Kaźmierczak, 2016] further infers that the words engineering and engineer come from an old French term. The French *ingénieur* is a man of creative mind, inventor, constructor (understood as a designer and contractor in one), a trained person with character, intelligence and talent. The author further emphasizes the approach in which an engineer is a person clearly associated with the world of technology, both due to education and performing the task using the knowledge and skills. In the time that has elapsed between the industrial revolution and modern times, i.e., the times of the fourth revolution [Industry 4.04], both the perception of the role of an engineer in society and the expectations related to performing this role change significantly. It is also associated with the threats of the Anthropocene era in which engineers must still “play” a significant role. Technical solutions can and should support the adoption of problem solving so as to save and renew all relevant resources – both natural and social [Kostecka, 2019].

The issue of preparing future engineers not only to perform specific tasks, but also to occupy and perform specific functions in society should become one of the criteria for evaluating education programs at technical universities. Perhaps, with the growing environmental and sustainable development awareness in society, such an approach will also find its practical aspect in encouraging young people to study at such technical universities, which will place the competence of recognizing and responding to ecological threat.

CONCLUSIONS

Waste, including packaging, is a serious problem in the protection of the natural environment. The role and size of the waste management sector is already large, but will grow rapidly, due to tightening of environmental policy in the EU and a shift towards a circular economic model. The demand for modern engineers in this industry is therefore very high.

Active education is an important tool in the hands of a teacher who wants to perform effectively. The greater the involvement of the listener (broadly understood as the use of senses, will, emotions, ways of processing information, etc.), the better learning will bring results. Therefore, the search for opportunities for students to work in groups and concepts such as: brainstorming, fish skeleton, mind map or bee swarm should be widely known and used by teachers – as well as universities.

Among the competencies of a future engineer in every industry, and especially a waste management engineer, apart from the traditionally understood ones, there should be the competency of recognizing and responding to ecological threats. It can be directly transferred to the implementation of broadly understood engineering tasks that take into account saving and renewing all relevant resources – both natural and social.

Despite no professional recognition of a waste management engineer in the current list of occupations in Poland, one can hope that it will soon be separated to support pro-environmental waste management and to be a driving force for other sectors.

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