DOI: 10.61905/wwr/208910

"Family Upbringing" vol. XXXII (2/2025)
„Wychowanie w Rodzinie" t. XXXII (2/2025)

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STEM Teaching Model as One of the Contemporary Educational Trends

Model nauczania STEM jako jeden ze współczesnych trendów edukacyjnych

Submitted: May 20, 2025 – Accepted: August 2, 2025

Abstract

Aim. This article discusses the STEM concept, which is currently a prominent educational trend aligned with existing policy initiatives. The aim of this concept is to enhance students' knowledge and skills in the relevant fields while equipping the younger generation with essential future competencies. The ultimate goal is to foster significant economic and social development and to boost innovation in various countries and regions.

Methods and materials. This article explains the concept of STEM by recalling the circumstances of its emergence, defining its meaning in educational and social contexts, and outlining selected theoretical frameworks related to the topic. It discusses the meaning of the acronym and its origins, examines different interpretations in public discourse, and explains methods and approaches to implementing this increasingly popular trend in education.

Results and conclusion. The STEM concept is one of the contemporary educational approaches that is being promoted in the constantly evolving landscape of the 21st century.

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Based on the arguments presented in the article, it can be inferred that its implementation will continue in the future. As economic growth and technological advancements progress in the fields of education and finance, new directions and principles for their development will likely emerge. This will enhance the foundations of the STEM concept and contribute to increasing the competitiveness of specific countries and regions.

***Keywords*:** STEM, education, 21st century, development, competencies of the future

Abstrakt

Cel. Niniejszy artykuł podejmuje temat koncepcji STEM, która jest obecnie popularyzowanym trendem edukacyjnym zgodnym z wdrażanymi inicjatywami politycznymi i społecznymi. Celem tej koncepcji jest zwiększenie wiedzy i umiejętności uczniów w odpowiednich dziedzinach (takich, jak nauki ścisłe i techniczne), jak również wyposażenie młodego pokolenia w tzw. kompetencje przyszłości (potrzebne do optymalnego funkcjonowania jednostki w stale zmieniającym się społeczeństwie). Ostatecznym celem jest wspieranie znaczącego rozwoju gospodarczego i społecznego oraz pobudzanie innowacji w różnych krajach i regionach.

Metody i materiały. W tym artykule wyjaśniono koncepcję STEM, przypominając okoliczności jej powstania, definiując jej znaczenie w kontekstach edukacyjnych i społecznych oraz przedstawiając wybrane ramy teoretyczne związane z prezentowanym zagadnieniem. Omówiono znaczenie akronimu i jego pochodzenie, przywołano różne interpretacje w dyskursie publicznym oraz wyjaśniono metody i podejścia w zakresie wdrażania tego – coraz bardziej popularnego – trendu w edukacji.

Wyniki i wnioski. Koncepcja STEM jest jednym ze współczesnych podejść edukacyjnych, które jest promowane w ciągle zmieniającej się rzeczywistości XXI wieku. Na podstawie argumentów przedstawionych w artykule można wnioskować, że jej wdrażanie będzie kontynuowane w przyszłości. Wraz z postępem wzrostu gospodarczego i postępu technologicznego w dziedzinie edukacji i finansów prawdopodobnie pojawią się nowe kierunki i zasady jej rozwoju. Jak można przypuszczać wzmocni to podstawy koncepcji STEM i przyczyni się do zwiększenia konkurencyjności poszczególnych krajów i regionów.

***Słowa kluczowe*:** STEM, edukacja, XXI wiek, rozwój, kompetencje przyszłości

Introduction

The reality of the 21st century forces individuals, among other things, to be flexible in action, to demonstrate the ability to adapt to many situations, and to perform a variety of (often simultaneous) social roles. This derives from the fact that individu-

als operate in a floating (Bauman, 2011; Melosik, 2013b), neoliberal, post-modernist reality (Charkiewicz, 2007). In a rapidly changing, technologized (Mrozowski, 2001) and consumption-oriented world (Baudrillard, 1988, as cited in Melosik, 1999, 2003), where automation and increasing competitiveness often dominate, the fluidity of labour and working environment in a broad sense (Gromkowska-Melosik, 2003) is widely prevalent and high ambitions and a focus on social and economic success are highly visible (Plebańska, 2018).

These changes of contemporary times cannot remain aloof from the educational system. It appears that very often changing values, lifestyles, ways in which individuals operate, and above all, currently implemented social and economic policies, imply (referring to the functional-structural theory) several multi-level changes visible also in the educational sphere (Melosik, 1994). The already mentioned professional space, which is constantly being transformed by the visible changes of modernity, may serve as an example. This opinion is confirmed by Norhaqikah M. Khalil and Kamisah Osman (2017), who stress that the "[…] the shift in this current world economy from a manufacturing-based to a knowledge-based economy, scientific innovation, augmented globalisation and advances in communication and information technology (ICT) have changed the job market in this modernised area" (Khalil & Osman, 2017, p. 225). The consequence of this situation is a rising demand for a highly skilled workforce that can tackle the challenges of the future and is equipped with a range of important and relevant contemporary skills to best respond and react to the challenges of the 21st century, these skills include: communication, collaboration, creativity, curiosity, adaptability, self-awareness, critical thinking, troubleshooting skills, and persistence (Cohen & Waite-Stupiansky, 2020). In accordance with the *Future Skills 2020 report* (Davies *et al*., 2011; Plebańska, 2018), this is a consequence of a number of factors, such as market saturation with increasingly new technological solutions and the growing popularity of artificial intelligence; the aging of societies (as we live longer); globalization and internationalization of companies, enterprises and the success of global corporations (which is associated inter alia with the phenomena of Americanisation (Iyer, 1993, as cited in Melosik*,* 2003); networks of socio-political and economic ties and their constant density; the development of global communication (*social media* and instant messaging) as well as progressive global informatization (Davies *et al.*, 2011; Grzesiak, 2020, Plebańska, 2018). This translates in a direct line into a concern for the youngest citizens so that already in the course of their learning experience (starting from preschool education and ending at its highest level) they are equipped with a number of key aforementioned skills and thus were prepared for the responsibilities and roles within these most valued professions in the future (Bogaj, 2003; Gromkowska-Melosik, 2011; Melosik, 2007).

The following paper focuses on an educational trend of my choice that falls under the acronym STEM (science, technology, engineering, and mathematics). It encompasses the current trend of prioritising areas of knowledge from this group and often treating them as highly valued and fully justified, given the observed transformations of modernity. At this point, however, it is worth noting that although the STEM education trend is not losing popularity, it is not the only one. Contemporary educational trends are often very heterogeneous and encompass many areas of knowledge, lines of development and guiding objectives, amongst which we can mention such examples as: mobile education, adaptive learning, snack learning, game-based education, outdoor education or gesture-based learning (and many others; Young Digital Planet, 2015).

This article focuses on STEM (Science, Technology, Engineering, and Mathematics) as a contemporary educational trend. It examines this topic by reviewing current literature, including scientific sources, reports, statistical data, and relevant websites. Additionally, it explores the significance and role of STEM education in today's world, as well as recent trends and social initiatives in this field.

STEM – Meaning and History of the Acronym

In the first place, it is worth referring to the beginnings of the popularity of the concept of STEM (relating to the four aforesaid areas of knowledge: science, technology, engineering and mathematics) and to reminisce about the year 2001, when it became widely recognised. The dissemination of the acronym STEM (the original version used the abbreviation METS and then SMET (Hunter, 2021) is connected to one of the National Science Foundation's scientific meetings (U.S. National Science Foundation, n.d.) in the United States and its acceptance by then NSF Director Rita Colwell (Marshall, n.d.). The transformation of the original wording of the acronym SMET into STEM was, in turn, due to Judith Ramaley[1] (Velarde, 2019). A specific turning point that initiated a long-term process of popularization of STEM education was, among others, the awareness of the growing role of innovations and technologies and their broadly understood connections with the economic and social development of given countries and regions, as well as with the general welfare (from a micro and macro social perspective. Report: *Rising above the Gated Storm*, released in 2005 by the U.S. National Academies of Science, Engineering, and Medicine) as well as research findings included in the reports: *Trends in International Mathematics and Science Study* (TIMSS) and the *Program for International Student Assessment* – PISA (the latter shows that in 2006 in the United States the as-

[1] American Biology and assistant director of education and Human Resources at the National Science Foundation.

sessment of the knowledge and skills of 15-year olds was not very optimistic – the country ranked 21st out of 30 countries surveyed; Velarde, 2019).

It can be assumed that the United States remains the key place where the concept of STEM education is being promoted, and despite the lapse of time, it is still a developing trend that holds a lot of promise. The United States and the United Kingdom are now considered to be highly influential countries in shaping this policy, where this model of education is particularly promoted and prioritised (Department of Education and Skills, n.d.).

STEM Education

At this stage of the analysis, it is worth explaining what STEM education is in essence based on. It can certainly be understood in a variety of ways and there is no one single general explanation of this concept, but according to the definition proposed by the Federation of American Sciences (FAS) in 2012, STEM can be conceptualised as: "Teaching and learning in the fields of science, technology, engineering, and mathematics. It typically includes educational activities across all grade levels – from pre-school to post-doctorate – in both formal (*e.g.*, classrooms) and informal (*e.g.*, afterschool programs) settings" (Velarde, 2019, p. 9). Firstly, it refers to education centred on the exact sciences in the broad sense. This is because they are considered to be of the utmost importance and prospective in the 21st century. Rodger W. Bybee (2013) distinguished four components of STEM literacy, which can be viewed as an explanation of what the approach actually is. Thus, in the first instance, the aforesaid author mentions "[…] knowledge, attitudes, and skills to identify questions and problems in life situations, apart the natural and design world, and draft evidence-based conclusions about STEM related-issues" (Bybee, 2013, as cited in Akerson & Buck, 2020, p. 6). The second component of his approach is: „Understanding of the characteristics features of STEM disciplines as forms of human knowledge, inquiry, and design" (Bybee, 2013, as cited in Akerson & Buck, 2020, p. 6). The third element of STEM literacy focuses on: "Awareness of how STEM disciplines shape your material, intellectual and cultural environments" (Bybee, 2013, as cited in Akerson & Buck, 2020, p. 6). The fourth factor refers to "[…] willingness to engage in STEM-related issues and with the ideas of science, technology, engineering and mathematics as a constructive, concerned and reflective citizen" (Bybee, 2013, as cited in Akerson & Buck, 2020, p. 6). All four components emphasise the multi-level nature of the concept itself, as well as its multi-textuality in terms of the undertaken actions, which all amount to one main objective – popularising the areas of knowledge from this group and raising awareness of their inestimable role in the present day.

As well as placing particular emphasis on learning exact sciences from the earliest years of a child's presence in the school environment, this approach is also characterised by a specific approach to learning in a broad sense. Such an approach appears to move away from the lecture method and is opposed to the theory-based transmission of knowledge divided into specific subjects. Instead, it provides an example of integrated education (Hunter, 2021) which focuses its particular attention primarily on the already mentioned four areas of knowledge (mathematics, science, technology and engineering) (Zintgraff *et al.*, 2020). Within this concept, education and teaching are interdisciplinary in nature and demonstrate that all four aforementioned areas are closely interrelated (Mansour & El-Deghaidy, 2021).

STEM is such an educational concept that combines mathematics, science, technology, and engineering, and in some cases, art is also included (then it is called STEAM education (de Bruin & Harris, 2017). Importantly, education in these disciplines takes place in the context of practical activities, experiments and exercises and in a holistic dimension – coherent and integrating the above-mentioned disciplines, showing their close connection and existing interdependencies. STEM education relies on solving real-life problems, seeking the best and most optimal paths, and is primarily focused on the aforementioned learning by doing. Therefore, the STEM concept reveals the interdependence and complementarity of different areas of knowledge, shapes an unconventional approach to extending knowledge, as well as provides preparation for independent undertaking of educational challenges and solving diverse problems that often go beyond the traditional framework of education. It thus fosters flexibility in thinking and readiness to face educational challenges, providing an introduction to the various challenges and unforeseen situations that individuals will have to face in the future. The essence of this approach is to shape competent, inventive and creative people who demonstrate flexibility in action as well as the capacity to solve novel and unconventional problems and to make decisions in an environment of constant change, which will guarantee success on the labour market. This can be substantiated by the statement of Russel Tytler *et al*. (2020), according to which "[…] in education there is increasing emphasis on students learning generic and translational skills/activities/dispositions to prepare them for work in order of the century. This is particularly the case for STEM, which is considered to be crucial to young's people's efforts to realise desirable future(s)" (Tytler *et al.*, 2020, p. 1).

STEM education programmes can be found as early as at the level of pre-school education (when they are limited to performing the simplest activities as an entry to mathematics education – such as an introduction to addition and subtraction), through school education, to master's (and even doctoral) studies, which testifies to the great popularity of education in this dimension in the present day (Midrack, 2023). The analysed tendency is a reversal of the classical and highly theoretical and possibly

rather predictable approach to education, showing it as a genuine adventure and above all as an indispensable introduction to adult life, which in the first place should provide not only knowledge, but above all, abilities to tackle a variety of situations. As already indicated, this concept is primarily focused on the ability to practically apply and deepen knowledge, while simultaneously proving that as a matter of fact, the things that we learn are not detached from our everyday problems (Zintgraff *et al.*, 2020). According to one of the websites on modern technologies, "STEM education typically uses a newer model of blended learning that combines traditional classroom teaching with online learning and hands-on activities. This model aims to give students the opportunity to experience different ways of learning and problem-solving" (Midrack, 2023, p. 3). Essential to this approach to education is the completion of projects, which will provide students with the opportunity to progress a range of skills relevant to contemporary life, through both individual and collective actions, which is regarded as an invaluable benefit in the future professional environment. This educational model emphasises the value of collaboration, which enhances the quality of the learning experience and effectiveness of that which students are currently engaged in. The focus on independence and creative thinking evident within this approach, as well as flexibility in action and the ability to adapt to changing situations, are of paramount importance, as it is perceived that present-day children will work in jobs that do not yet exist today. This is corroborated by the accelerating pace of changes and transformations of current reality that are being witnessed and that justify the materiality of this concept from the perspective of its centrality in the socio-economic dimension (in the long-term).

Notwithstanding the fact that elements of the STEM education model can nowadays be noticed in almost every school, the National Research Council lists four principal categories of programs that educational institutions provide in an effort to develop knowledge and skills in these areas. Thus, the first category includes the *elite or selective STEM-focused schools* for exceptionally talented students whose academic interests involve STEM fields. These are schools that equip students with the knowledge and skills within these disciplines at a very high level and are designed to prepare graduates for further education in the exact sciences and future careers in STEM-related professions. The second category listed is *inclusive STEM-focused schools*. These are educational institutions that do not have a requirement to meet admissions criteria; however, they offer knowledge and equip students with skills which fall within STEM disciplines. Some of them are guided by the mission to facilitate the educational process, as well as future careers, for social groups that are not well represented in the STEM field (*e.g.*, women or national and ethnic minorities). Another category comprises the *STEM-focused career and technical education* (CTE) *schools or programs*, which involves popularising careers in the STEM fields with a special interest in those falling into the group of students bearing the intention of abandoning their education.

The final distinguished category is *STEM programs in comprehensive schools that are not STEM-focused*. As the name suggests, these programmes are intended to further empower, equip with particular skills and sometimes reward the most ambitious, highest achieving students. One of such programmes is Advanced Placements or International Baccalaureate Programs (National Research Council, 2011).

As already noted, STEM education transcends traditional frameworks, also considering the activities and actions realised as part of specific coursework. The four main areas of knowledge that constitute the object of this article, which compose the acronym STEM, are likewise not pursued schematically and predictably. Hence, for example, *science* incorporates engineering, modern technology and mathematics into the conducted experiments, while *technology* has to do with 3D printing, mobile technology, Internet of Things, data analysis, programming, digital prototyping and modelling, as well as game development. Another area of knowledge — engineering — covers such issues as electronics, electrical engineering, civil and mechanical engineering and — especially popular nowadays — robotics (Khine, 2017). The last discipline — mathematics — provides a more advanced dimension from the earliest years of schooling and "[…] incorporates concepts and exercises that apply science, technology, and engineering to mathematics" (Midrack, 2023, p.8). In order to fully realise the STEM concept throughout the project activities, the classroom space is often completely redesigned, *e.g.,* through the rearrangement of tables and at times students even leave the building and their daily workstations, for the quality of the activities to increase (United States. Congress. House. Committee on Science, Space, and Technology, 2013). Occasionally, in this educational tendency, the learning process also involves collaboration with professionals in the given field, so that students are able to train in a way and under conditions that are as close as possible to the actual ones that will await them in a professional environment.

The Importance of STEM Concepts

At this stage of the analysis, it is worth raising the question of why the trend towards STEM education is not decreasing in popularity. It appears to be meaningful not only from the micro-social viewpoint in terms of deciding on the future of particular individuals and equipping them with a set of important, currently relevant skills and such a level of knowledge which will allow them to successfully realise themselves in professions valued in the 21st century, but also from the macro-social perspective corresponding to currently visible global tendencies (National Research Council, 2011). It is often claimed that education in these areas is of the utmost importance for the economic development of the countries and regions concerned (Kelley & Knowles, 2016), for boosting their

competitiveness, for their prominence in the international arena and for their social well-being as a whole (Mansour & El-Deghaidy, 2021; Leonard, *et.al.*, 2019). For it is reckoned that graduates who specialise in these areas will perform "critical roles in scientific discovery, technological progress, and innovation. And […] workers in STEM occupations on average have higher wages and lower levels of unemployment than those in non-STEM occupations" (United States. Congress. House. Committee on Science, Space, and Technology, 2013, p. 22). Moreover, these areas are often described as (what has already been noted) being more esteemed, and consequently better paid, which is directly linked to higher financial gratification for those who pursue professional activities within these areas (Jason Velarde states that "[…] according to the Bureau of Labour Statistics (BLS), STEM occupations earn a median wage of nearly $76,000, which is more than double the median salary of $35,080 for all workers" (Velarde, 2019, p.23).

Numerous researchers draw attention to the range of skills and the holistic, interdisciplinary approach to education that the STEM concept implements and focus on the relevance and economic usefulness of the competences acquired in the learning process, in the future within the framework of the students' fulfilment of their professional duties in adult life (United States. Congress. House. Committee on Science, Space, and Technology, 2013) thus becoming a valuable, active part of *knowledge economy*, knowledge society (Mansour & El-Deghaidy, 2021). Furthermore, most (if not all) of nowadays' professional areas are regarded as more or less related to STEM areas. This is a consequence of progressive technological development and, hence, the necessity to adapt to changing conditions, which is related to the ability to benefit from the achievements of science and technique and to possess sufficient expertise to continue to discover and improve things. Notably, it is worth remarking at this point that STEM specialisations include such fields of study as: Engineering, Earth sciences, Health sciences, Information technology, Mathematics, Physics, as well as Astronomy, Biology, Computer science and Chemistry, which provide a wide range of career opportunities in the future (University of the People, 2024).

At this point, it is worth highlighting that the STEM education model is currently popular not only in the United States, from which it originated. For instance: "In 2018, the White House's Office of Science and Technology Policy issued a report and Federal strategy for all students to be able to access STEM education" (University of the People, 2024, p. 22) or even the United Kingdom, but this model of education already represents a trend of a transnational character and is well-known almost worldwide. This is evidenced by the numerous actions, social campaigns and teaching programmes that correspond closely with its objectives (Wee Teo *et al.,* 2022). In Poland, the idea of education in the spirit of STEM is propagated by, *inter alia*, the Polish Association of STEM Education in Gdańsk (Innowacje STEM dla Przyszłych Pokoleń [STEM Innovations for Future Generations], n.d.).

Besides that, in Poland, among others, the Educational Foundation "Perspektywy [Perspectives]" undertakes many initiatives aimed at the promotion of educational and then professional areas, which reflect the aforesaid educational tendencies, such as: *Dziewczyny na Politechniki* [Girls on polytechnic university]*, Dziewczyny do* ścisłych [Girls to exact sciences] (Szymczak, 2016), *Nowe Technologie dla Dziewczyn* [New technologies for girls]*, It for She, Lean in STEM, Lean in High Tec*h or the Conference: *Perspektywy* [Perspectives]*. Women in Tech Summit* (Fundacja Edukacyjna Perspektywy [Educational Foundation Perspectives], n.d.). In addition, it is worth stating that the promotion of STEM education addresses educational inequalities through supporting the academic interests and subsequently the careers of women and minority students, by stimulating investment in these fields of study, and by enhancing their sense of empowerment and self-confidence while pursuing their individual interests and preferences in this area. Basically, this educational model assumes that everyone — regardless of their differences (in terms of categories such as race, class, gender or ethnicity) — is able to develop their STEM competences. As can be remarked, this corresponds closely with the assumptions of meritocratic theory (Melosik, 2013a).

Criticism of the STEM Concept

As with any concept, this one also encounters criticism, which on this occasion relates to the undervaluation of other subjects such as literature and writing, art and music, due to an overemphasis on STEM fields of study alone (which might justify, for instance, the parallel popularisation of the acronym STEAM incorporating the arts, which can be beneficial in equipping people with the appropriate competences in a field of study such as architecture) (University of the People, 2024). Additionally, the acronym itself has been subjected to multiple modifications and transformations as well as *complements* (*e.g.,* eSTEM – where electronics or STEMM — in this case, medicine — have been appended to it; Hunter, 2021). Furthermore, it is considered that inducing an excessively large number of people to invest in these fields of study will not lead to filling a gap in the — still developing and increasingly technologized — labour market, but — if too high an amount of students is incentivised in excess of the current demand — may in some cases – inversely proportional to the intended effects — result in (while referring to the concept of Raymund Boudon (Boudon, 2009) — aggravation of unemployment in certain professions corresponding to these fields of knowledge (Midrack, 2023). Furthermore, it is acknowledged that investing in STEM fields of education requires resources, time and effort – which is directly related to the need for financing, taking into consideration the use of modern technologies, as well as equipping, through education or costly training, with the right level of competences, knowledge and skills,

which frequently constitutes a long-term process requiring the participation of teachers who are highly qualified and prepared for this education model (University of the People, 2024).

Conclusion

On the basis of the foregoing, it can be recognised that the STEM educational concept is one of the current key educational trends with worldwide reach. With the passage of time, not only does it not cease to be relevant and, on the contrary, it continues to obtain new adherents in various parts of the world, even those most distant from the United States. The merits of this educational model undoubtedly entail equipping students with a range of qualities and skills, including self-reliance, high ambitions, capacity for decision-making, creativity, ability to cooperate, critical thinking, inventiveness, perseverance despite setbacks and problem-solving ability (Howarth & Scott, 2014). Conceptually, STEM also involves an awareness of continuous technological development and the ability to act and work in accordance with the latest, most up-to-date technological solutions, remaining constantly abreast of them, whilst also recognising the role played by innovation of many kinds nowadays. STEM education entails learning to master changing circumstances and a broad sense of empowerment, knowing that one is capable of tackling any problem or situation. Ultimately, STEM constitutes an educational process that provides students with a range of skills that are both important and crucial in the 21st century (Akerson & Buck, 2020; Velarde, 2019).

Whereas, as already alluded to, investing in the exact sciences does not represent the only educational trend observed today, as can be presumed, it will certainly accompany us in the forthcoming years. It is beyond any doubt, however, that the policy of investing in STEM fields of education analysed in this study is definitely one of the currently attractive possibilities of rendering education more appealing and modern, which will consequently transform into education that is *close to reality* (Young Digital Planet, 2015), aiming at increasing the level of knowledge and skills and providing the so-called *competences of the future* (Ismail, 2018) in the interest of the best possible economic and social development and the growth of innovativeness of particular countries and regions (National Research Council, 2011). As it is claimed, the future of the world depends precisely on these four key areas of knowledge: science, technology, engineering and mathematics, expertise in which is particularly important today. The aforementioned statement is reflected in the opinion of the National Science Foundation US that:

> In the 21st century, scientific and technological innovations have been involved in importing as we face the benefits and challenges of both globalisation and a knowledge-based

> economy. To succeed in this new information-based and highly technological society, students need to develop their capabilities in STEM to levels much beyond what was considered acceptable in the past. (U.S. National Science Foundation, 2007, p. 2)

While preparing this article I encountered the statement that "[…] STEM is a microcosm of life" (University of the People, 2024, p. 21), which is to some extent substantiated by the foregoing arguments which demonstrate the comprehensive impact of this educational concept on the lives of individuals at the micro level and entire societies at the macro level, while at the same time maintaining the high competitiveness of the given countries and regions (National Research Council, 2011). It can therefore be foreseen that this tendency will not fade in the near future and will still persist.

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