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EDUCATION FOR SUSTAINABLE DEVELOPMENT – PLANNING THE DIRECTION OF EDUCATION IN THE FIELD OF INFORMATION TECHNOLOGIES

EDUKACJA DLA ZRÓWNOWAŻONEGO ROZWOJU. PLANOWANIE KIERUNKU KSZTAŁCENIA W OBSZARZE TECHNOLOGII INFORMACYJNYCH

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Abstract: The paper was mainly intended to establish whether parents of children aged between 7 and 14 are interested in teaching them modern information technologies, and to develop an adequate methodology for evaluating the children's aptitude in the process of teaching these issues. The survey questionnaire was addressed to 1,116 parents of children aged between 7 and 14. As suggested by the research, there is a considerable interest in the process of children's education and development of their digital competence regarding the following IT spheres: computer graphics, programming, and animation. The paper also presents the concept of a diagnostic platform, which will contribute to the adequate profiling of the didactic material in terms of the students' predispositions through an interactive mode of observations. The presented concept can also bear an auxiliary function when potentially determining the further developmental path of the child.

Keywords: education for sustainable development, aptitude assessment, eye-tracking.

Streszczenie: Głównym celem artykułu jest ustalenie, czy wśród rodziców dzieci w wieku 7-14 lat jest zainteresowanie nauczaniem nowoczesnych technologii informacyjnych dotyczącym ich dzieci oraz opracowaniem właściwej metodyki oceny predyspozycji dzieci w procesie nauczania tych zagadnień. Ważnym aspektem w edukacji dla zrównoważonego rozwoju jest określenie kierunku trwałego doskonalenia się i ulokowanie odpowiednio zidentyfikowanego potencjału uczącego się. Dlatego tak istotne jest jak najwcześniejsze określenie jego

predyspozycji, począwszy od etapu edukacji podstawowej. Analiza była możliwa dzięki zbadaniu preferencji rodziców w celu opracowania innowacyjnej metodyki oceny predyspozycji ich dzieci w procesie nauczania technologii informacyjnych. Kwestionariusz ankiety został skierowany do 1116 osób – rodziców dzieci w wieku 7-14 lat. Jak wynika z badań, istnieje duże zainteresowanie procesem edukacji dzieci i rozwijaniem ich kompetencji cyfrowych w następujących obszarach IT: grafika komputerowa, programowanie, animacja. W artykule przedstawiono również koncepcję platformy diagnostycznej, która przyczyni się do odpowiedniego profilowania materiału dydaktycznego pod kątem predyspozycji uczących się poprzez interaktywny tryb obserwacji. Przedstawiona koncepcja może pełnić także funkcję pomocniczą przy potencjalnym wyznaczaniu dalszej ścieżki rozwoju dziecka.

Słowa kluczowe: edukacja dla zrównoważonego rozwoju, ocena predyspozycji, *eye tracking*.

1. Introduction

Education for sustainable development has many aspects. One of them is to enable learners to access knowledge and acquire skills that will guarantee sustainable development at various stages of their life (Morzol, 2006). Industry 4.0 is embedded in the strategy of sustainable development with its specificity focused on the use of information technology in its entirety.

The education system should adapt to the realities of a growing Industry 4.0. One of its key tasks should be to educate "engineers 4.0" to guide individual countries through the transformation process related to the digitalization of production processes. An example of such good practice is the holistic model of student education introduced at the University of Applied Sciences in Darmstadt, Germany aimed at activating competences in Industry 4.0 (Simons, Abé, and Neser, 2017).

As noted by Ziemba et al. (2016), education for sustainable development needs new models and forms of development. It should be borne in mind that the education of future engineers should not begin as late as in secondary school and be carried out in a targeted and intensified manner at university level, but it should start as early as childhood. At this point it is possible to indicate the essence and individualized character of development areas. An example may be the most sensitive period in human life, between 3 and 6 years of age. This issue was presented in the framework of the UNESCO Directive resulting from the report "Recognizing the potential of ICT in early childhood education, 2010" in the context of the impact of information and communication technologies on the development of children and youth (Kalas, 2010).

For the modern generation of young people, the omnipresence of IT solutions is a natural situation, and the skills to use them are immanent. Therefore, it is important to educate children at an early age preparing some of them for such professions which now probably do not yet exist but will be demanded shortly due to the industrial transformation (Lindahl and Folkesson, 2012). This is primarily a matter of organizing workshops where – through adequately applied educational methods – it will be

possible to stimulate some interest in children, e.g. in high information technologies. There is plenty of research documenting the need for early identification of pupils' aptitude, allowing their further profiling and recommendation/indication for further education (Gelman and Brenneman, 2004).

Children are creative, open to the world, they absorb knowledge, hence it is worth supporting those attitudes, at the same time allowing them to develop their interests (Lindstrand and Brodin, 2014). It is increasingly the case that children are passionate about programming classes and high information technologies. Under the tutors' guidance, they can learn about programming, design, and control of robots in the form of toys. What is more, group activities teach children how to work in a team.

The main aim of the research was to determine whether parents of children aged between 7 and 14 are interested in teaching them advanced information technologies and to develop an adequate methodology for evaluating the children's aptitude within the IT teaching process. The research problems were formulated by asking the following questions:

- Are the parents interested in teaching their children IT, and if so, in which subject areas?
- Is there any interest on the part of parents in implementing an innovative methodology for assessing children's aptitudes, and if so, how important is it for their professional development?

To clarify these issues, a survey was conducted on 1,116 parents of children aged 7 to 14. Based on the performed literature study and a survey questionnaire, the paper proposed a concept of methodology for assessing the children's aptitude in the IT teaching process adopting a mobile diagnostic platform. As a final result, this will allow not only to assess the children's aptitude in such a broad range of issues as is related to IT, but also to develop a mechanism for creating current content and forms of teaching, combined with a diagnostic and evaluation function of the used eye-tracking technique. The implementation of the developed methodology can therefore help parents to choose their child's career path and professional future.

2. Literature review

In taking care of their children's future, parents direct them to additional activities where they can improve various skills. They are usually related to learning foreign language, but programming and broadly understood computer graphics classes are becoming more and more popular. If a child's initial enthusiasm as a "young engineer", "young graphic designer" or "young robotics engineer" turns into passion, it will enable the parents to choose their child's career path and professional future. Forecasts concerning the Polish labour market indicate that the demand for professions such as IT specialists, robot coordinators, specialists for modelling and interpretation of production data, and graphic designers will be very high.

The factor affecting the shape of children's and youth's aptitude is also the dynamization of IT development. This arises from the theory of technological determinism. It shows the correlation between the technological and the mental (Holloway and Valentine, 2001).

Toy robots allow not only to develop the so-called hard competencies, e.g. in programming and algorithms, but they also stimulate creativity. By introducing the youngest generation to the world of new technologies, they stimulate their visual and spatial imagination and shape their technical intuition. Interactive activities, for example in the programming of toy robots, are a kind of intellectual exercise, and they create very good conditions for developing logical thinking, planning, and problem-solving skills. Children learn about the complex world of information technologies easily and pleasantly, observing their practical applications (Holloway and Valentine, 2001).

The discussion on defining and assessing the children's aptitude has continued since the beginnings of pedagogy. Parents and teachers have some difficulties in effectively recognizing the characteristics of a child who is capable or talented in a particular direction; new definitions of gifted students have been developed over the years. Zimbardo talked about intelligence as a general ability to use experience, while Stern said that "intelligence is the ability to adapt to new requirements through the use of appropriate means of thinking". The definition proposed by Lewowicki is still popular among Polish researchers, who believed that "a gifted student is one who shows an above average level of psychophysical development, combined with cognitive curiosity and a high level of motivation, manifested in an independent and consistent search for answers to his/her questions" (1986). Most of the researchers, however, generalized the definition of capability, often combining, for example, intelligence with physical fitness. Hüther and Hauser went one step further and formulated a thesis that there is some potential in every child (Hüther and Hauser, 2012). They also noted that numerous childhood aptitudes are not directly related to school knowledge and skills, which makes them even easier to ignore. This is particularly important, especially in the context of new technologies. Nowadays, with the growing role of various types of specializations in the economy, the search for aptitude in specific spheres of development, or even particular areas, has been undertaken in the case of children. Global digitalization has made the IT talent a desirable feature for the youngest (Byron, 2008).

Although the so-called narrow specializations are desirable in the labour market, it is impossible to assess whether a child has the right aptitude. There is a close connection between many areas of IT and numerous fields of mathematics, so the following can be mentioned among the features that may indicate IT aptitude: algorithm, logic, spatial thinking skills, and the ability to understand a formal structure of a task (Daley, 2011).

Research conducted by Gruszczyk-Kolczynska et al. proved that there are already plenty of children with these talents in preschool groups (Gruszczyk-Kolczynska,

Zielinska, and Grabowska, 2003). Interestingly, however, their number decreases with the start of school. When looking for a future IT specialist in a child, one should not either overlook the general features which characterize gifted students such as the ability to observe profoundly, broad interests, natural curiosity, and frequent initiatives in numerous aspects of everyday life and education. This is the only way to distinguish children who simply enjoy the pleasures provided by computers, games, and the Internet, from their peers who would like to explore the secrets of IT and investigate how e.g. their favorite computer game has been created.

One of the basic tools for testing mathematical and informational talents are specialist directional tests such as the Progressive Achievement Test – PAT (Caldwell and Hawe, 2016) and the Scholastic Aptitude Test-Mathematics SAT-M (Dynarski, 1987). In particular, the latter is used in application processes for colleges in the USA, however there are no similar tools in Poland. The following methods are distinguished:

- intellectual diagnosis by identifying strengths and weaknesses,
- diagnosis of interest,
- general IQ tests,
- control kits for recognizing scientific capabilities developed by G. Lewis,
- multiple intelligence questionnaires.

The following tools can also help diagnose a child's abilities: interest survey, observation at work, didactic measurement, examination results, and participation in extra-curricular activities (competitions, Olympics, scientific projects).

A distinction should also be made between both diagnosing and supporting talent development at different stages of the education process. In preschool and early childhood it is crucial to stimulate active, creative tasks, as this is a simple way of discovering a child's previously hidden abilities. Learning about various areas of the surrounding reality also has a direct impact on broadening the child's horizons, arousing curiosity about the world. Personality is shaped at an early school age, therefore it is also the time when the first aptitudes manifest themselves. There is no doubt that access to new technologies, smartphones, tablets, computers and interactive boards, supports and facilitates the educational process, and it may be a stimulus for creative activities. It is important to observe a child in this period because one can see then some signs of potential aptitudes, such as ease and speed of learning and memorizing information from certain areas, creative problem solving, etc.

At the teenage stage, the search for one's own identity begins, and thus the focus is on a particular area of life. Among children with IT aptitude, there will be 'artists' for whom the field for self-realization will be, for example, in the possibility of designing graphics and graphic interfaces of websites, and 'analysts' gifted with logical thinking. However, developing such predispositions requires a lot of patience, concentration, and hours spent in front of the screen.

As a part of the research on cognitive processes, including learning, eye tracking assisted techniques gain significance (Delucchi, Neugebauer, Dröse, Prediger, and

Mertins, 2019; Jarodzka, Holmqvist, and Gruber, 2017). Eye-tracking, a technique of tracking the movement of the eyeballs, is often effectively adopted in the marketing industry to watch customers' behaviour (Stolinska and Andrzejewska, 2017). The use of eye-tracking is much wider – it is also used in psychology and medicine. Eye-tracking tests enable a non-invasive, precise analysis of saccade movements and serve to determine the trajectory of eye movements (Léger et al., 2018).

The eye tracking technique is more and more often used to support and monitor educational processes (Rodrigues and Rosa, 2019). Thanks to its use, two types of data can be recorded: fixations, i.e. points at which the eye view has stopped, and saccades, i.e. eye movements, during which the eyesight is transferred from one observation point to another (Tai, Loehr, and Brigham, 2006). This is how objectively the activity of the audience or observers can be examined and, as a result, their cognitive process understood. Eye-tracking helps to find the answer to many questions: How long does it take to observe selected, interesting elements/objects? In what order does the recipient see them? Which elements are noticed, which are ignored, and how often do the eyes return to the perceived elements? Both the visual starting points and the readers' pathways make it easier to determine the optimal structure of a text or infographics for the learning process. This is how the effectiveness of learning processes can be effectively increased. Studies confirm that, of all the senses, most information from the environment reaches the brain through sight. It is estimated that the eyes receive about 80% of stimuli (Poole and Ball, 2005).

An important area in research on the elementary and university education system is also the observation of the transformation of the functioning systems and development models to the requirements declared in education for sustainable development. The conducted scientific considerations show that the course of transformation is not fully integrated with the concept of education for sustainable development, and missing here, among others, are properly constructed curricula (Leal Filho et al., 2018). Such content should activate the involvement of learners. The conclusions in the research show the need to identify the factors supporting potential activities at different stages of education. It can be assumed here that it is advisable to identify the aptitude of learners, which will strengthen the effect of the expected commitment. The ease of acquiring knowledge, resulting from field skills, will be an element triggering increased participation in classes.

3. Research results determining the level of interest in the methodology of predisposition assessment

The first stage of the study was the analysis and criticism of literature, which showed the purposefulness and originality of the research problems under study (bibliographic query, desk research).

The planned research works included surveys. Then, a methodology for assessing children's aptitude in the IT teaching process using a mobile diagnostic platform

was proposed. For the study, a research tool in the form of a questionnaire was developed, the sample size was determined, and the method of communication with the respondents defined. Following the field research, their results were compared and analysed, and conclusions drawn.

A part of the research was an attempt to determine whether parents of children aged between 7 and 14 are interested in IT education with the parallel evaluation of the children's aptitude in particular areas. Therefore, whether there was also a need for a modern method for assessing children's aptitude in information technology areas. The following themes in the field of technology were identified for this reason: robotics, programming, animation, graphics, electronics as well as areas proposed by the parents. The selected areas were subject to the surveys of whether a parent is interested in selecting any of these areas for their children. The research was conducted in the form of a questionnaire addressed to all educational institutions in Częstochowa (public primary schools). Answers were given by 1,116 parents.

Due to the declared age range of children, two groups were distinguished in the research. This was also due to the current division of classes in the Polish educational system. A distinction can be made between the first stage of education (early childhood education−integrated education), classes 1 to 3, and the second stage, comprising classes 4 to 8 (subject education). Following the division formed in the educational "ecosystem" in this way, two different groups of parents of classes 2 to 3 and 4 to 7 were indicated here, and the research was conducted within these groups. Based on the obtained results, the subject considerations were carried out.

In the first block of questions, the respondents specified the degree of interest in their child's participation in additional activities, followed by particular attention to IT classes (Table 1).

Table 1. Interest in the child's participation in additional classes – the parents' perspective

Question	Answer: Yes
Would you be interested in your child's participation in additional classes?	80%
Would you be interested in your child's participation in information technology classes?	74%

Source: own study.

To clarify the potential direction of learning in the further part of the questionnaire, parents could choose from the field categories presented. They could select the following thematic areas: robotics, programming, using the Internet, animation, electronics, and others. The areas of greatest interest were computer graphics (71.0% of parents), programming, animation (Figure 1). Interestingly, the Internet was of little interest (23.1%). This was probably because its presence was defined as a natural element of a contemporary child's life.

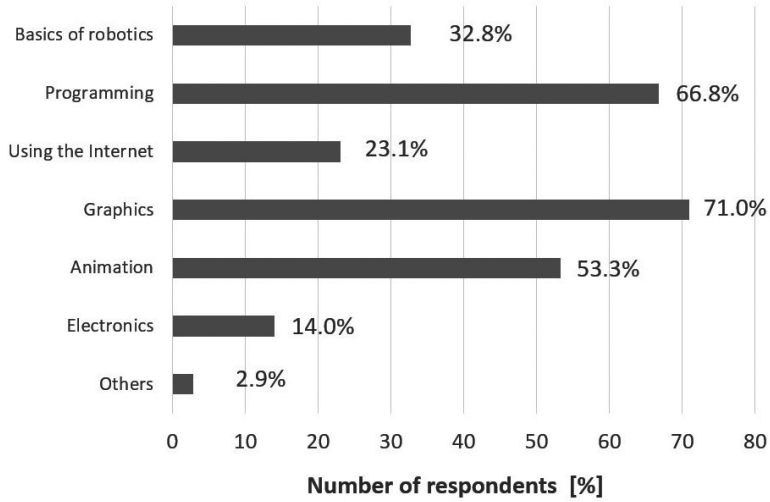

Fig. 1. Children's interest in information technology thematic areas – the parents' perspective

Source: own study.

An important element in the survey was also the identification of the recommendations for the characteristics of the classes (Figure 2).

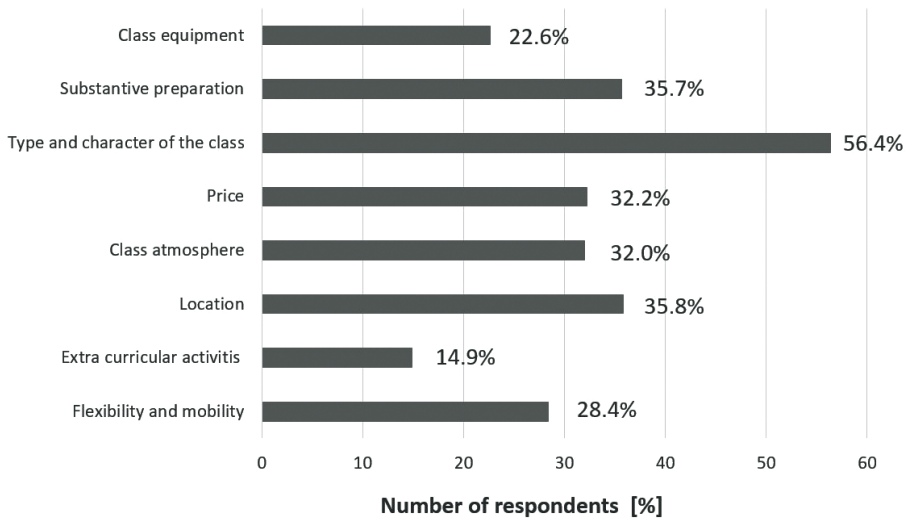

Fig. 2. Important features taken into account by parents when choosing additional activities for their children

Source: own study.

The following set of features was taken into account here: the type and nature of classes, the substantive aspect of their conduct, their location and potential flexibility (the concept of a mobile school), room equipment, atmosphere, etc. At this point, the majority of parents (56.4%) indicated the importance of the nature and type of thematic issues. Important factors were also: location (35.8%) and the substantive preparation of the tutors (35.7%). The first factor was also the premise confirming the concept of assumed mobility of the proposed solution.

Table 2. Parents' interest in using innovative methodologies to assess children's aptitude in the IT teaching process

Question: *Would you be interested in using the innovative methodology of assessing the children's aptitude in the IT teaching process?*	
Yes	67%
No	15%
Hard to say	18%

Source: own study.

An important point of the surveys was also to obtain information on the interest in implementing an innovative method for the children's aptitude diagnosis (Table 2). As many as 67% of respondents showed interest here.

4. Developed methodology

According to the proposed methodology, the authors' research focused on the aspect of identifying children's cognitive aptitude for learning subjects from the areas of high information technologies. The rationale for doing so comes from the results of the research presented in this paper. It should also be noted that in the literature on the subject it is difficult to find similar studies on the degree of parental interest in the implementation of the methodology of aptitude assessment with the use of eye-tracking. The analysis of the results obtained from the questionnaire surveys allowed for the decision to start further work on the assessment of the aptitude of children with the use of eye-tracking.

The assumed analysis was performed in real-time during the conducted classes. In light of this, the integration of two processes can be assumed, educational and diagnostic. The latter will also determine the nature of the curriculum content introduced within the classes. This assumes the interaction between the identified aptitude that conditions engagement and the effectiveness of knowledge acquisition with the information made available during learning. This aspect is related to the form of presentation of didactic content and its substantive scope. The following were examined: the degree of focus, the involvement of children in the course of the classes. What is more, the analysis in question provided the basis for defining

effective teaching material that will involve course participants (children in this case). It was assumed that due to the indicated demand (potential mobility), the research infrastructure could be located in a specialist vehicle, with a possibility to move the research apparatus and educational background to any target premises constituting a mobile laboratory.

The implementation of the developed methodology can therefore help parents and school to choose a child's career path and professional future. Thanks to the mobility of the proposed diagnostic and educational platform, the social dimension of the solution will be extremely important. A specialist vehicle with advanced equipment and software can reach children living in a small town, thus eliminating the barriers that result from the availability of children for modern methods of evaluation of their aptitude, teaching methods, and information technologies.

The diagnostic character of the proposed mobile solution (diagnostic platform), the laboratory, will allow, through an interactive mode of conducted observations (interaction at the level of analysing the predispositions of the course participants and adjusting the content of teaching), to properly profile the didactic material from the areas of information technology. This could result in the development of auxiliary teaching material for use in the primary program or extended and extracurricular activities. The research results can become the added value for educational institutions by providing information constituting a broad spectrum of suggestions for state schools and training institutions. This direction is consistent with the conclusions of the research conducted by Sun and Hsu (2019).

The next stage of the conducted research was to develop a conceptual diagnostic system using dedicated research equipment and applications to support the process of monitoring and analysis of cognitive processes in the course of thematic training. The sections of training would cover such matters as programming, robotics, graphics, and animation. These courses would be educational, performing research and diagnostic functions in real-time, assessing the cognitive aptitude of the course participants in the area of information technology (based on the assumed problematic issues).

The measuring equipment will consist in the following devices: eye trackers and BCI (Brain-Computer Interface), providing a layer of acquisition and aggregation of information obtained during the courses. The efficiency of learning (as a cognitive process) is largely determined by the perception and processing of stimuli coming from the environment, and research by van Rijn et al. (2019) indicated that the use of eye trackers among children may be an objective technique for early development analysis. Monitoring of those processes may be effectively carried out by devices that register and analyse the movement of the eyeballs, which is also confirmed in subject studies (Lai et al., 2013). This would be done with the use of an eye tracker, which, among other things, will identify in real-time the degree of involvement of the course participants and analyse the correctness of the selected materials of the trainer, and bring objective information related to real aptitude regarding the

character of the classes. It is important here, as emphasized by Strohmaier et al. (2020), that the interpretation of eye movements should be based on a reasonable assumption of what eye movements measure and what cognitive processes these measures reflect. A complementary element of the procedure of registering and analysing the processes of effective learning would be the use of BCI – measuring devices allowing to examine brain activity with electroencephalography. BCI enables noninvasive monitoring of EEG rhythms, an important aspect is also the possibility of registering emotional states.

The aggregated information collected during the measurements would be processed in the program layer to explore output variables describing aptitude towards selected subjects. At the end of the course, the potential abilities of children in the areas correlated with the specifics of the courses would be identified. Matlab scientific and programming environment would be implemented in the software layer, based on which an intelligent system for diagnosing predispositions can be created.

Testing devices – eye trackers – comprise several basic elements: a camera tracking the movement of the pupils (using infrared light), a camera registering the examined object, software that applies a graphic trajectory of eye movement and visual stopping points to the examined object, and a computerized central unit performing the necessary calculations and being the place of data recording. Moreover, the device provides information about the large number of parameters that are important for a comprehensive evaluation of the person's brain activity, such as: dwell time, blink count, fixation count, fixation frequency, fixation total, fixation duration average, fixation dispersion average, scan-path length, saccade count, saccade velocity, saccade velocity average, saccade latency and many more.

The use of the proposed equipment (eye trackers and BCI interfaces) is justified by a number of research projects in the field of education. Eye tracking technology was used to test students' attentional preferences and learning paths, and ultimately to improve the effectiveness of online learning (Mu, Cui, Wang, Qiao, and Tang, 2019). It was also used in research on the usability of a web application supporting the learning process remotely (LMS – Learning Management System). The conducted research showed that the issue of the usability of the LMS system is of key importance. Students' ICT skills vary, and the shortages of ICT were particularly pronounced among students in developing countries and an important factor that hinders their learning (Pretorius and van Biljon, 2010). It has also been proposed to use an Eye-Controlled Interactive Reading System (ECIRS), which uses human eyes instead of a traditional mouse to control digital text to support screen reading. The study involved a group of students who used the ECIRS and Mouse-Controlled Interactive Reading System (MCIRS) while learning English (reading plain text and Q&A articles). The results of the conducted research confirm that highly interactive digital text reading patterns with ECIRS support increase motivation and willingness to learn, giving students a more intuitive

and natural reading experience. Online article reading with the support of ECIRS directs students' attention to deeper digital reading than MCIRS due to the simultaneous integration of perceptual and cognitive processes of selection, awareness and control based on the movement of the human eye (Chen et al., 2018). The literature on the subject emphasizes that in order to build adaptive learning systems, designers need to identify patterns of student behaviour and provide adaptive teaching materials accordingly. When analysing the data on eye movement, the examined students were classified into two groups – visualisers and verbalisers. Both groups presented significantly different eye movement patterns as confirmed by eye-tracker fixation data (Luo, O'Steen, and Brown, 2020).

5. Conclusions and implications

The authors believe that the methodology for assessing children's aptitude in the IT teaching process using a mobile diagnostic platform, proposed in the paper, is a foundation for one of the crucial assumptions of industrial transformation towards the so-called Industry 4.0 – namely the appropriate preparation of staff. This is directly related to the necessity to formulate new content and forms of professional education along with new specialisations, with an emphasis on improvement in the significance of engineering professions – including ITmation engineer, robotics engineer, and graphic designer.

Thanks to the mobility of the proposed diagnostic and educational platform (which is the basic component of the methodology), the social dimension of the solution is extremely important. A specialist vehicle with advanced equipment and software can reach children living in a small towns, thus eliminating the barriers that result from the availability of children for modern methods of evaluation of their aptitude, teaching methods, and information technologies. Eye-tracking research allows for a better understanding of students' cognitive abilities – the processes of selecting and memorizing information, directing attention, responding to new problems and tasks. Eye-tracking also contributes to the interdisciplinarity of educational research, as it allows us to explore the neurobiological aspects of the learning process and to use knowledge about brain work to increase learning efficiency and improve teaching methods.

The article focused on the assessment of the degree of interest in the introduction of the aptitude assessment method based on the proposed methodology. The authors presented an outline of the methodology with the use of eye trackers, assuming the continuation of research and implementation of a utilitarian solution.

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