Chapter # 9

A FRAMEWORK FOR EARLY DETECTION OF WEAK SIGNALS OF STEM-RELATED APTITUDES

Alina Florentina Grigorescu (Pîrvu) & Cezar Scarlat
Doctoral School of Entrepreneurship, Business Engineering & Management, National University of Science & Technology POLITEHNICA, Romania

ABSTRACT
The present work aims to establish a research framework and an appropriate procedure for the assessment and identification of emerging skills related to STEM (as weak signals) from primary school so that students have the necessary training and support to adapt to universities and future workplaces. As methodology, the study is based on directly observed and/or personal experienced cases in the Romanian engineering higher education as well as pre-university education cycles, which are complemented by pilot tests designed for this purpose. Secondary research (literature survey) marks the literature gap and complement the matter under investigation. Since this is a pioneering effort, several challenges are foreseen. This project can be risky in the long term because positive/negative outcomes can occur, requiring a step-by-step approach. Nevertheless, the lessons learnt, and implications are important for the main stakeholders: education policy makers and administrators, students and professors alike (Grigorescu & Scarlat, 2025).

Keywords: technical higher education, engineering skills, STEM (science, technology, engineering, mathematics) competencies, STEM-related aptitudes, early detection of weak signals.

1. INTRODUCTION

In the second half of the 19th century, in psychophysics, the theory of signal detection appeared. A century later, it came back to life when it was discovered that the sensations generated by neural noise do not fall below the threshold of awareness. More adequately called the theory of “weak signals” detection, the philosophy and model of this theory was conceptualized by both Gaussian and non-Gaussian models. It proved to be useful when earlier the signals are detected, then better. The applications have extended time spectre – from avoiding a negative phenomenon with rapid evolution (in medicine or catastrophic earthquakes) to predicting future evolution of a certain system, in a large range of areas: from electronics to strategic management (strategic early warning system) and economics (agriculture or market prediction). The decision can also vary according to time, the area of application, starting from fractions of seconds or minutes in case of catastrophic events, or weeks or months in the field of agriculture.

While the extant literature is rich in many areas (psychophysics, neuroscience, psychology, medicine, electronics and telecommunications, geophysics or economy), the literature related to applications of weak signals theory in education (engineering studies in particular) is almost non-existent. Engineering skills – part of STEM (Science, Technology, Engineering, Mathematics) competencies – are trained during costly engineering studies. However, cases of engineers less talented or unhappy with their engineering jobs are sometimes met. The authors had the opportunity to meet young people with non-engineering studies, but who occupy jobs with technical profiles. In these situations, family influence and career guidance achieved during school are the main reasons for the discrepancy between the young people's studies and the chosen workplace.

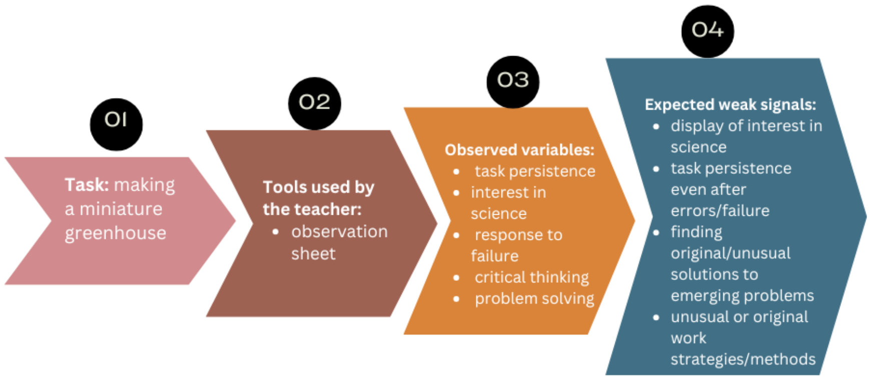
Weak signals in the STEM context are, in fact, micro-cues found in psychometric or behavioral data. A combination of existing instruments would be far more useful in identifying weak signals than a single test, because early detection requires integrating cognitive, affective, and behavioral variables (Ahlqvist & Uotila, 2020).

STEM weak signals can be cognitive, behavioral, affective, or a combination of these, and they can be measured through various psychometric tests. For example, unusual or original problem-solving strategies may constitute weak cognitive-behavioral signals (Hencke et al., 2022). Providing original responses to scientific or technical tasks, or combining concepts in unusual ways, can also constitute weak signals in the STEM field (Almeida et al., 2008).

With regard to affective weak signals, these consist of students' sustained interest in experimental activities or empirical research, demonstrating intrinsic motivation for learning science (Shawn et al., 2011). In addition, the reformulation of strategies and persistence in tasks even after encountering errors may represent a weak signal (Zimmerman, 2007), as can atypically accelerated trajectories in specific domains (Allensworth, 2013).

Figure 1 presents an example of a task that could lead to the identification of certain STEM weak signals. The use of such activities to identify STEM weak signals could help support the development of STEM-talented students and prepare them to obtain jobs for which they are well equipped, thereby improving the quality of education. Moreover, equipping STEM-talented students with domain-specific competencies helps them be better prepared for the labor market in general, providing skills that enable them to cope with the multiple challenges of an ever-changing society.

Figure 1.
Example process for identifying weak STEM signals.



Source: Authors

The present study aims to develop a suitable research framework and methodology for the early identification and assessment of emerging STEM-related skills (seen as weak signals) during pre-university education cycles, with the aim of facilitating better correlation between students, their future engineering education and subsequently their engineering careers.

2. LITERATURE SURVEY

Many studies on the perception of weak signals began in 1970 in the field of strategic planning. In recent years, research has also emerged in other fields, using different terms, which has led to various descriptions of weak signals (Van Veen & Ortt, 2021).

Early warning systems initially emerged within military and security frameworks to identify threats to national security. Currently, the concept of early warning has been successfully applied in the context of maintaining stability in the international security environment (UN, NATO, etc.), natural disaster forecasting, epidemic control, as well as in project and business management. The advantages of using such a system include identifying and learning lessons, proactively recognizing opportunities and threats, scenario analysis, and laying the groundwork for strategic business simulations (Popescu & Scarlat, 2015).

Weak signals employed in the process of identifying unforeseen events, such as diseases, come from the realization that these may be warning signs of accidents or other crises, identified only in retrospect. Frequently, weak signals are ignored if they go against general expectations about the future or if they are unusual, or if they don't agree with traditional ways of privy to things (Liff, Eriksson, & Wikström, 2017).

Often, weak signals are emerging phenomena that are the first signals of a major change that is about to happen. Observing weak signals can identify the seeds of change and classify them. The "standard" theoretical base is represented by the Ansoffian perspective. This requires the weak signal watcher to identify linearly progressing problems in their early stages. In formulating the premise of weak signal theory, the "standard" version of this theory assumes an emerging problem perceived in its rudimentary form. Weak signals represent not only the identification of a linear emergence, but also the changing positions and contexts of observers (Ahlqvist & Uotila, 2020).

The theory of weak signals in medicine is successfully used for the early detection of rapid negative phenomena, such as the evolution of diseases. The biggest challenge facing those responsible for improving and regulating patient safety is how to identify, integrate and act on early warnings and weak signals of risk before they contribute to a catastrophic failure of care (Macrae, 2014).

In geophysics the weak signals are also successfully used, specifically in predicting catastrophic earthquakes. The prediction of an earthquake is challenging, with many countries conducting extensive research on this topic. Using the local cross-correlation tracking method can reflect the correlation between electromagnetic data (Xie et al., 2022).

In public education, early skills have become an important issue for teachers, which are essential for them to investigate ways to close the gap in academic achievement to the national level. Pathways to future academic achievement are, in most cases, shaped in the early years, when children learn essential skills that help create a foundation for later development of a set of academic skills and achievement. Many studies emphasize that many children possess certain early abilities, thus having an advantage over their peers in the process of achieving academic performance (Hein, Smerdon, & Sambolt, 2013).

Regarding the development of STEM potential, this includes expanding students' capacity to understand and appreciate certain deep mathematical ideas, concepts, or scientific notions, perseverance in challenging explorations, and the belief that mathematics and science are valuable and that mastering complex concepts requires diligent effort (Adams et al., 2008). Students considered talented are those who demonstrate above-average performance in one or more achievement domains. According to the Talent Development in Achievement Domains (TAD) framework, talent development is conceptualized as dependent on multiple factors, with an emphasis on person-related variables such as abilities, personality traits, and acquired competencies. These variables, i.e., the predictors of talent development, partially vary depending on the domain. Therefore, abilities, personality traits, and acquired competencies are positively correlated with the development of performance and creative productivity in STEM fields (Preckel et al., 2020).

Moreover, at the international level, several studies support the idea that early talent identification and differentiated interventions can prevent the loss of potential and support the development of adaptive and innovative STEM profiles. For example, Sedeaud et al. conducted an analysis of key elements to consider in talent identification. These are: (1) understanding and illustrating the early influences on performance, (2) implementing individualized performance trajectory models, (3) applying corrective adjustments based on relative age, biological factors, and training, and (4) improving the estimation of potential through a holistic approach that integrates “life pathways” (Sedeaud et al., 2025). Therefore, such talent identification is essential to ensure that students are as well-prepared as possible for the labor market.

Early detection of skills is essential for achieving educational and professional success. In the field of engineering education, identifying STEM (science, technology, engineering, mathematics) skills from pre-university education can have a positive influence on the career guidance process and help students choose careers that suit them and they bring satisfaction and fulfilment. When these early skills identification mechanisms are missing, individuals end up in unsuitable careers, leading to unfulfillment and burnout. This idea is supported by a study conducted within global companies that shows that low-performing employees are from technical fields, but prefer managerial fields, and those who report low levels of professional burnout are those who have a career fit (Biron & Eshed, 2017).

The integration of weak signals theory in the field of education can also be approached through its connection with established educational theories, such as social constructivism (Vygotsky) and Experiential Learning Theory (Kolb). Based on constructivist theories, teachers can observe and subsequently leverage weak signals in students’ behavior, identifying emerging interests or yet unexplored talents. This contributes to the personalization of learning and the development of competencies based on the talents identified.

Furthermore, Experiential Learning Theory posits that people learn through the transformation of experience. Thus, by engaging in diverse experiences, students have the opportunity to reflect on them, formulate principles or lessons, and then apply them in various contexts, thereby repeating the learning cycle and developing specific competencies. Detecting and analyzing weak signals creates a culture of reflection and adaptability, contributing to effective talent management in an educational context and aligning teaching strategies with current and future societal challenges.

Therefore, weak signals not only anticipate future trends but also contribute to continuous adaptation based on flexible benchmarks, while remaining aligned with student-centered educational paradigms and the development of individual potential. It is necessary that teachers and other educational actors are able to detect weak signals of students regarding these abilities for the early detection of abilities. Weak signals are not just simple "weak evidence of future changes” but represent starting hypotheses for a lot of future-oriented knowledge processes. Rossel (2012) mentions that there are a number of research topics that support the idea that weak signals are easy to identify and the constructivist position that places weak signals within a complex system. On the other hand, despite the fact that weak signal detection theory has been successfully applied in fields such as medicine, economics or telecommunications and strategic management, its application in education, and especially in the field of engineering, is still unexplored territory.

A 2016 study provides a detailed analysis of seven core STEM courses, examining how resources were used and their correlation with final grades. Through logistic regression, researchers observed that students who extensively use exam preparation resources have higher chances of achieving good grades, whereas those who rely more on lectures have lower chances (Waddington et al., 2016).

Recent technologies can be used effectively in Early Warning Systems (EWS) to predict students who are suitable to pursue STEM disciplines further, as well as those who are at risk of not succeeding. Therefore, both teachers and students can make informed decisions to provide support and guide towards the best solutions. Leveraging the wealth of data generated on online learning platforms, the use of EWS can predict students with low chances of success before the end of the semester (Yu & Wu, 2021).

As global trends such as Artificial Intelligence (AI) and machine learning are increasingly being integrated into the field of education, the framework proposed in this article aims to improve strategies for personalizing students' educational trajectories, providing them with opportunities to participate in interdisciplinary and experiential activities to develop competencies relevant to the digital labor market.

A recent study on the integration of artificial intelligence in STEM education highlights that such integration contributes to methodological diversity and to the discovery of global perspectives on personalized STEM education enhanced by AI (Sun et al., 2025). Therefore, artificial intelligence can help facilitate the personalized learning process, which is also one of the ultimate objectives of the proposed early identification framework. Through personalized learning, based on the STEM weak signals exhibited by students, they can more easily reach their full potential.

Early Warning Systems could help students remain engaged in the STEM field and ultimately secure employment opportunities within this domain. By identifying struggling students early on, educators can intervene promptly with targeted support strategies tailored to the specific needs of each student. In Chicago, many schools have used early warning indicators to develop strategies for improving student performance and examine patterns in the indicators to strategically address students' low performance based on specific issues observed in the school (Allensworth, 2013).

Integrating students' behavioral signals and entry profiles helps predict their success in STEM courses. Behavioral signals such as the number of correct responses to in-class questions, slide and video views, can serve as stable predictors of students' success throughout the semester. Using behavioral signals and student profiles enables the prediction of student success. Also, early warning systems that leverage diverse student data can aid in developing other innovative predictive features for student success and contribute to designing an enhanced early warning system (Nam & Samson, 2019).

Recent studies strongly recommend using early warning systems to identify at-risk students. A study conducted in 2018 examined eight prediction methods and investigated the optimal timing for implementing such a system within a course. The study's findings indicate that the ideal time for implementing an early warning system is around weeks 5-6 (Howard et al., 2018).

This chapter proposes a novel approach and framework for the early identification and assessment of emerging STEM-related skills as weak signals during pre-university education cycles and it is largely based on preceding studies. Such an approach is necessary because today's society is evolving rapidly and the amazing technological progress puts a lot of pressure on educational experts to provide students with adequate training from the earliest ages, so that the skills they acquire will be useful to them in the future workplace. Teachers must be able to identify, assess and develop the skills of each student, and for this to be possible they need effective methods and tools to identify weak signals of students. It should also be mentioned that the discrepancy between the educational offer and the needs of the industry highlights the need for universities to offer appropriate study programs to train future engineers, and for the professional requirements of education to be integrated and aligned with the requirements of the labor market (Grigorescu & Scarlat, 2024).

3. METHODOLOGICAL APPROACH

The methodological approach of this study is a mixed one and consists of direct observations and personal experiences of the authors. Observations were conducted at the pre-university level in a private high school in Bucharest, Romania, over the course of an entire school year, with 18 fourth-grade students aged between 9 and 10. The observed activities took place both in formal classroom settings and during extracurricular activities dedicated to integrated STEM initiatives (including programming sessions, problem-solving through simple experiments, and hands-on projects). Observations followed an informal rubric developed by the authors, focusing on elements such as students' initiative in technical activities, duration of attention span, types of strategies used in problem-solving, teamwork, and responses to open-ended tasks. To ensure data consistency, the authors systematically recorded emergent behaviors immediately after each session and triangulated these notes with reflective discussions among the researchers.

Additionally, the authors conducted observations at the university level at a public university in Bucharest, Romania, involving first-, second-, and third-year engineering students. The observed activities took place in classrooms during formal teaching sessions and practical applications. The number of students varied throughout the academic year (between 20 and 60 per group), depending on participation in the courses and seminars delivered by the authors. Data on students were collected through direct observation and spontaneous discussions with participants. Subsequently, the data were categorized according to identified behavioral patterns (e.g., approaches to technical tasks, collaboration style, resilience in facing open-ended problems, initiative in projects) and then analyzed thematically.

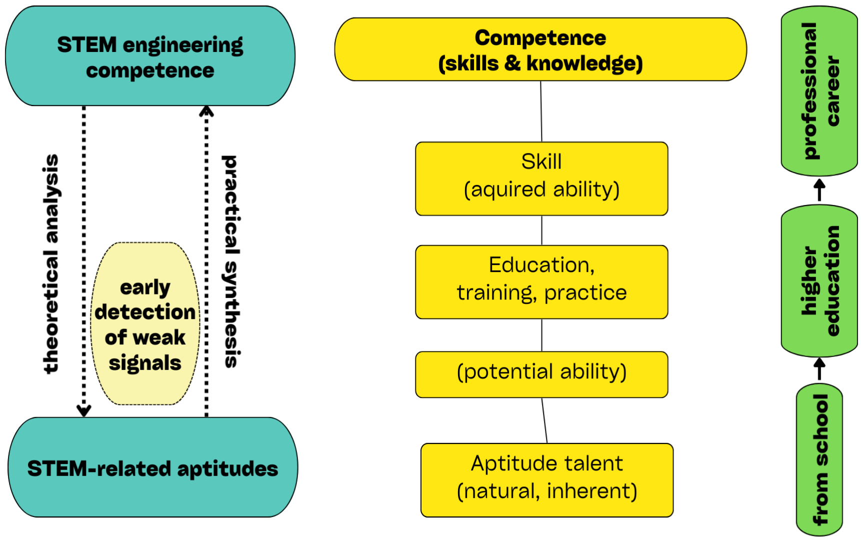
To strengthen interpretations, the authors also sought additional evidence in the data, including concrete examples of recurring behaviors and the frequency of observed patterns. Currently, the study does not include images or quantitative statistics, but such documentation is planned for the next phase of implementing the weak signals identification framework.

Also, the study includes secondary research (specialty literature analysis) that highlights the existing gaps in the profile literature and supports the theoretical framework of the investigation. The adopted methodology is one with an exploratory character, considering the fact that the application of the theory of weak signals in education is too rare, especially in the field of engineering education.

The authors' observations are intended to optimize the orientation of students towards an appropriate engineering education, so that young people are oriented towards a career that suits them according to their potential and interests. This is a pioneering initiative and is only the first step towards a procedure and tools for identifying emerging weak STEM signals. The authors anticipate several challenges, including risks associated with false-positive or false-negative results. Therefore, the methodology proposes a gradual approach, allowing adjustments along the way and learning from accumulated experiences. The implications of this research are relevant to several stakeholders: educational decision-makers, teachers, students and administrators of educational institutions.

This study contributes to developing a suitable research framework and methodology for the early identification and assessment of emerging STEM-related skills (*Figure 2*), aiming to facilitate *better correlation between students, their future engineering education and their future engineering careers.*

Figure 2.
A scheme of research approach.

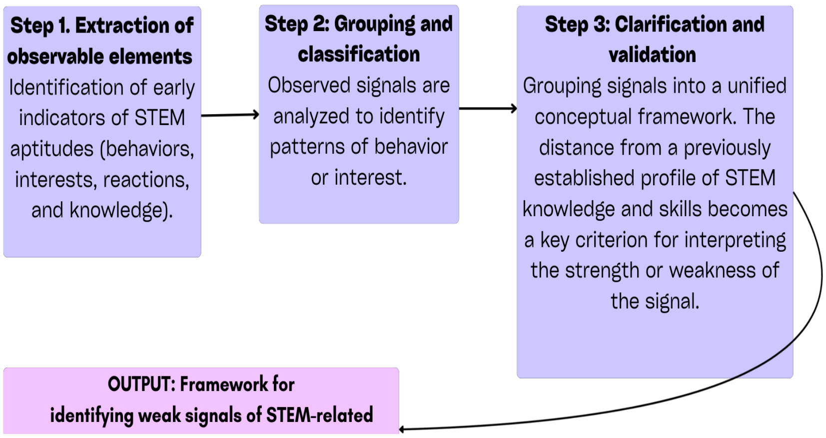


Source: Authors

This article represents an important step in the process of creating a framework for early detection of weak signals of stem-related aptitudes. The methodological framework for detecting weak signals associated with STEM skills was made by adapting the three-step approach proposed by Van Veen & Ortt. The authors of this approach claim that the "weakness" of the signals is defined as the distance from the frame of reference of the perceiver, and the three stages proposed by them are: the perception of the signal, the interpretation of the signal and its implementation (Van Veen & Ortt, 2021).

Starting from the three-step approach of the authors mentioned above, the weak signals detection framework is presented in the figure below. This provides a tool for the early detection of STEM skills by extracting observable indicators (behaviours, interests, reactions, knowledge, etc.) that may signal the emergence of STEM skills. Next, these indicators can be grouped into recurring patterns and different levels of "weakness", and finally these signals can be integrated into a conceptual framework, where the degree of distance from the student's previous knowledge and skills becomes the main criterion to evaluate the strength or weakness of the signal.

Figure 3.
Weak signals detection framework.



Source: Authors

The previously proposed framework aligns with the logic of existing early warning systems used to identify students at educational risk but focuses on the early detection of weak signals of STEM potential.

An example of such an early warning system is the Early Warning Mechanism in Education (MATE) in Romania. This is an institutional and procedural framework based on a set of tools designed to identify students at risk of dropping out or leaving school prematurely, with the aim of supporting them to continue and complete their studies, based on early signals recorded in Romania's Integrated Education Information System. The framework relies on real-time data collection regarding early signals (low academic performance, grade repetition, absences, inappropriate school behavior), helping teachers and other decision-makers implement appropriate and immediate measures to mitigate risks and problems identified among students (https://mate.edu.ro/).

Similarly, the proposed weak signals detection framework seeks to systematically identify observable indicators (interests, behaviors, reactions, etc.) that could signal the emergence of STEM competencies. This helps teachers plan learning activities in line with the talents identified among students to support the development of specific skills. Thus, early warning systems like MATE transform incipient risk signals into support actions, while the proposed framework transforms STEM weak signals into starting points for counseling, academic guidance, and the design of educational trajectories aligned with future STEM careers.

4. FINDINGS

To identify talented STEM students in primary school, the authors made direct observations of the students' involvement in STEM-related activities. An example of such activity was the design and 3D printing of key chains. The students worked in teams of two, at the computer, where they designed, based on predetermined models and with the help of specialists, personalized key chains. They also had the opportunity to print them using 3D printers. During the activity, there were students who demonstrated critical thinking, good logical and analytical thinking skills, but also spatial and technical thinking.

These children, if they *benefit from an educational process that supports them in developing these skills, have a high chance of achieving a successful career in engineering*. An example of an activity carried out within the primary cycle is that of building a city from recyclable materials. In this activity, students worked in teams, collected the right materials, designed and built a miniature city. They also had the task of building a bridge that would support the weight of a toy car, but also a simple circuit with batteries and light bulbs that would take the place of the street lighting in their city. The activity stretched over several hours, and the students had limited resources at their disposal. Students who managed to find innovative solutions and solved the problems encountered during the project were noted. Through this activity, one can observe students who have the ability to solve problems, who have an increased interest in science and technology, but also spatial and technical thinking. It is an activity that can help teachers identify students' weak signals and develop them in the future.

In pre-university education, preparing students for the labor market and for life in today's constantly changing society is also achieved through various projects and programs implemented at the national level. Two such programs are called *"Green Week"* and *"School Otherwise"*. Within these programs, students are given the opportunity to participate in extracurricular activities through which they develop different skills and gain knowledge from various fields. The diversity of activities and of the people students come into contact with helps them discover more about their own talents, making even weak signals of STEM aptitudes more visible. Teachers play a key role in observing these weak signals in time in order to encourage and help students work on identifying and strengthening their abilities.

An example of an activity where students can discover their STEM skills is related to robot programming. Students take part in workshops where they learn how to build a robot from scratch and program it to perform simple tasks. These activities take place in several stages, giving those who show interest and passion for this field the opportunity to advance and carry out increasingly complex activities. Another important aspect is the opportunity to participate in various competitions with the robots they have built.

Another example is represented by activities carried out by parents within these programs. Parents are invited to class to present their profession and engage in different activities with students. They can also organize activities at their workplace. VanMeter-Adams et al. argue that students gain their interest in STEM from extracurricular experiences as well as childhood events, while hands-on lab activities sustain this interest. The same authors highlight that community-based programs involving both children and their families are essential in sparking and maintaining long-term interest in STEM (VanMeter-Adams et al., 2014). One such activity in which students had the opportunity to learn more about STEM and test their abilities was a visit to a power station. During the visit, students observed how the station functions, used certain equipment under staff guidance, completed tasks using VR (virtual reality) tools, and worked in teams to solve specific challenges. During these activities, teachers were able to observe passionate students and those showing weak signals of STEM aptitude.

Another type of extracurricular activity where students can express potential weak signals related to STEM is the *Science Fair*. In this event, students present their projects and compete for prizes that may include experiences (e.g., visits to museums, institutions, workshops) or material rewards (toys, laptops, school supplies, etc.). Students prepare for the fair months in advance and are guided by teachers throughout their preparation. They can also seek help from parents or specialists from various fields, but the actual work is their own. Participation is based on registration, and students can register individually or in teams. To validate their registration, they must present the project plan and the stages they will follow to complete it. Examples of such projects include: a bicycle that generates electricity, smart water filtration systems, recycling systems, a smart nightstand, robots for the visually impaired, and other projects aimed at improving people's lives and reducing pollution.

Therefore, extracurricular activities within nationally implemented programs (and beyond) can help teachers identify students' weak signals, making it easier to recognize those with a natural inclination toward STEM. Once such students are identified, teachers can support them in improving their skills, provide activities that nurture their curiosity, and offer guidance regarding their future.

As far as hands-on STEM experiments, making a volcano using baking soda and vinegar is one of the activities that get students engaged and engaged. This type of experiment gets students interested in science and technology, but also tests their collaboration, teamwork, or logical thinking skills. In the university environment, game-based activities involving STEM simulations, such as programming robots or solving virtual challenges through educational software, are effective methods of testing students on their STEM talents and abilities. During these activities teachers can gather valuable data about students' talents and how they can help them develop further. Another type of test is one that is based on logical rip-puzzle activities or reasoning problems that aim to assess students' critical and analytical thinking. These activities give teachers the freedom to customize them according to the theme of the course, while also testing the students' skills/weaknesses in the STEM field.

These tests and experiments, based on a representative sample, should provide a clearer picture of the process of identifying weak signals among pupils and students, the results being useful in drafting recommendations for teachers and educational counselors regarding the career guidance of students.

Figure 2 shows the route taken by the students, starting from primary school and ending with a professional career. The authors propose this route model that could be followed in order to identify weak signals of students early, based on the progressive development of their skills. First, it emphasizes the native aptitudes of individuals, that is, those innate traits that reflect natural talent and inclinations. The second step is the analysis from the perspective of the student's potential, evaluating his latent ability to learn and progress in certain areas. Next, the emphasis is on acquired skills, developed through education and practice, thus consolidating what the student has already learned and is able to apply in practice. The end of the path is completed by the achievement of competence, which sums up the skills, knowledge and attitudes necessary to perform successfully. The proposed model provides a clear framework for understanding and supporting student progress from potential to performance, i.e., from low signals to achievement.

In terms of activities observed in the university environment that can help teachers identify weak signals of students, an example of an activity is represented by problems that put students in difficulty and test their ability to solve problems, think logically and criticism, but also teamwork. One such problem is related to finding an optimal solution for street lighting in their city. The students worked in teams and had access to resources such as course materials and the internet, creating a sustainable street lighting project. In this way, students who have problem-solving, collaboration, teamwork, problem-solving, and spatial and technical thinking skills were noticed.

Participation in conferences and workshops is encouraged. Students are supported to participate in such activities by presenting scientific papers or participating in debates on current technological topics. In this way, students are motivated and can discover or develop their STEM talents or skills. Such informal activities are extremely beneficial for students and add value to the instructional-educational process. It is also in such situations that teachers can identify students who show talent in the STEM field and help them develop further to reach their full potential.

5. LIMITATIONS AND FURTHER STEPS

The present research has several limitations; the first one being related to the lack of longitudinal data. In addition, the lack of concrete data on the application of the tests among pupils and students is another major limitation. In addition, false positive or false negative results should be considered in terms of the application of weak signal theory in education. The authors propose the continuation of the process of carrying out a procedure to evaluate and identify emerging skills related to STEM (as weak signals) during pre-university education cycles. The previously presented pilot tests are to be applied among pupils and students, and then the results of the participants will be analysed for validation. The authors also propose the development of tools to be applied in pre-university education with the aim of identifying weak signals related to STEM, thus contributing to increased chances that young people who choose to study STEM disciplines in university to have higher chances to be successful while pursuing an engineering career (Grigorescu & Scarlat, 2025).

6. CONCLUSIONS

In the field of education, the theory of weak signals could be successfully applied by teachers, thus helping students to develop their natural talents and thereby form skills and then competencies that will help them in their future careers. The implementation of an early warning system would help in the career guidance process; thus young people would no longer end up occupying positions or different fields that do not suit them Since we live in a society that requires talented STEM workers capable of facing challenges, teachers and other decision-makers should place greater emphasis on systematically observing STEM activities in the classroom, identifying and nurturing weak signals in order to provide differentiated tasks, collaborating with parents and the community to offer students diverse experiences that motivate and spark their interest, and promoting project-based and experiential learning. This creates opportunities for students to develop not only STEM competencies but also skills that help them thrive in an ever-changing society.

Thus, the methodology used—based on direct observations, educational experiences, and the analysis of specialized literature—supports the idea that weak signals theory can be successfully applied in education. Moreover, the application of the model proposed by Van Veen & Ortt (2021), structured around perception, interpretation, and implementation, provided a useful framework for the early identification of STEM weak signals among students. Through practical STEM activities, contexts can be created for identifying early signals of STEM aptitudes, and teachers' observations during these activities, correlated with skills such as critical thinking and creativity, illustrate the presence of weak signals.

The research therefore emphasizes the importance of early identification of STEM skills among pupils and students, considering their impact on educational and professional success. The application of the theory of weak signals in the field of education, especially in engineering education, can positively contribute to the process of adequately orienting students towards careers in the technical field, highlighting the students' potential. The studies presented and the observations made by the helpers contribute to a better understanding of this complex process of identifying weak signals and using them for the benefit of students. Early identification of STEM talents can support students in choosing an appropriate educational and professional path, thus eliminating unfulfillment and burnout. Implementing early warning systems and using practical tests and experiments can help teachers use valuable tools to support the development of these skills. However, as a relatively new approach to education, the application of weak signal theory requires a flexible and adaptable framework that can be adjusted as more experiences and data accumulate (Grigorescu & Scarlat, 2025).

The declared purpose of this chapter is to exemplify how the talents and aspirations of young people for a certain career can be detected as early weak signals (in this case the engineering career), but the "early detection of weak signals" approach can be used, *mutatis mutandis*, in the case of any other career. One of the important reasons that led us to choose engineering studies for this essay is the significant dropout rate in this field (Grigorescu, Scarlat & Simion, 2025).

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AUTHORS' INFORMATION

Full name: Florentina Alina Grigorescu (Pîrvu)
Institutional affiliation: Doctoral School of Entrepreneurship, Business Engineering & Management. National University of Science & Technology POLITEHNICA (Romania)
Institutional address: 313 Splaiul Independenței, Bucharest 060042
Short biographical sketch: I have been a primary school teacher since 2015 and I am currently a PhD student at the Doctoral School of Entrepreneurship, Business Engineering & Management within the National University of Science & Technology POLITEHNICA, Bucharest. In recent years, I have conducted several research studies in the field of STEM education and published multiple articles, such as *"Preparing Students for Successful Business Careers in a Changing Society: Effective Methods and Strategies"* published in *Springer Proceedings in Business and Economics – Rethinking Business for Sustainable Leadership in a VUCA World*, *"Early Detection of STEM Skills during Secondary*

Education: A Weak Signals Approach" in *Education and New Developments 2024*, and *"The Use of New Educational Technologies for Preparing Students in Engineering: An Innovative Perspective on Entrepreneurship and Competitiveness"* at the *International Conference of Management and Industrial Engineering*.

Full name: Cezar Scarlat
Institutional affiliation: Doctoral School of Entrepreneurship, Business Engineering & Management. National University of Science & Technology POLITEHNICA Bucharest (Romania)
Institutional address: 313, Splaiul Independenței, Bucharest 060042
Short biographical sketch: *Professor Emeritus* of National University of Science & Technology POLITEHNICA Bucharest, and PhD Supervisor at the same university, he has taught Technology Entrepreneurship, Business development and strategy, Marketing as well as related courses at universities in Romania and abroad (Finland, Portugal, Belgium) – as visiting/exchange professor. Holding master's degrees in electronics engineering and international business, and a PhD degree in management and industrial engineering, *Dr Scarlat* acquired international experience by post-graduate studies in Romania and abroad (USA, Canada, UK, France, Italy); research and study tours in Europe and North America; project management expertise by participation in about 50 international projects.
Director of the Center for Business Excellence for almost two decades (1991–2009) and then running private consultancy, he co/authored about 50 books and over 200 articles and scientific reports in his interest areas (higher education included). Membership of international bodies and scientific/editorial boards. Academic reviewer for journals and prestigious publishers.