Research Report on Technology Promotion

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Management Summary

This report consists of two parts. The first part focuses on what is required to implement the working method according to the principles of Intervention Mapping within the field of Technology Promotion. The second part outlines the results of the literature review on promoting the choice of technology among students aged 9 to 15.

Part 1: Intervention Mapping for Technology Promotion

To support policymakers in making a step towards financing and executing impactful Technology Promotion[1] initiatives, Part 1 delves into the use of Intervention Mapping in the context of Technology Promotion. This involves not only what developers (e.g., program managers and project leaders) in Technology Promotion need to do, but especially how they can be facilitated. Working in a systematic and evidence-based manner, as desired by policymakers, requires a behavior change among developers. Self-efficacy, skill, and having sufficient knowledge are not only determinants that influence student behavior (see Part 2), but these determinants are also important for Technology Promotion developers, who create programs for students. Therefore, Part 1 offers an initial theoretical exploration of what is needed to effectively implement the working methods according to the principles of Intervention Mapping within the Technology Promotion sector. The application of the Intervention Mapping methodology by leading Dutch organizations provides insight into possibilities for implementing the methodology in practice.

By making the "Technology Promotion Checklist" available, it could be possible to clarify to Technology Promotion developers what is expected of them to "develop methodologically sound and scientifically underpinned programs." The Technology Promotion Checklist that has been developed outlines 10 steps for the development, implementation, and evaluation of technology promotion programs, based on Intervention Mapping.

Part 2: Literature Research

The scientific literature databases Pubmed and ERIC were systematically scanned for articles related to the exploration of behavioral determinants influencing the choice of technology among young people and articles that examined the effectiveness of technology promotion programs. From these international databases, 24 articles were selected, supplemented by two additional articles provided by the Regieraad. Additionally, one article from the *Platform Talent voor Technologie* website was selected for the current literature review. Finally, three more articles were included based on the reference lists of included articles.

The literature review suggests that increasing students' self-efficacy and skills in STEM subjects, providing practical and career-oriented information, and emphasizing the relevance and connection of technology with important societal themes are essential to guide more students towards a technical education and career profile.

Interventions, hereinafter referred to as programs, consisting of integrated STEM education varied in effectiveness, as did the effect of extracurricular STEM activities. This indicates that it is important not to conclude in advance whether a particular type of program does or does not work. The way a program is developed, whether it connects with the target group, and the person or persons implementing the program are also essential factors in determining how impactful a program will be.

[1] With Technology Promotion, all activities are meant that aim to inspire a target audience to choose an education or career in technology. In this research, the target group consists of children and young people aged 9 to 15 years.

Despite the relevant information obtained from the literature review, it is important to recognize that the scientific quality of the included studies was often low. Causes for this include the use of small samples, the absence of a control group alongside the intervention group, the exclusive use of qualitative evaluations, and the limited statistical analyses performed on available quantitative data. Based on these findings, it can be concluded that research on technology promotion, especially when compared to research on, for example, medical interventions, is still in its infancy. To move the field of Technology Promotion, which has so far been strongly vision-driven, towards better scientific substantiation, it is important to join forces. This is necessary both to support developers and to take a step towards:

1. A methodological, theoretically, and empirically substantiated approach to program development.
2. Establishing connections between ongoing projects.
3. Identifying effective initiatives.

It is also essential to improve the accessibility of research already conducted in the Dutch context and, where possible, to centralize result findings.

Part 1

Intervention Mapping: A Methodology to Improve the Quality of Technology Promotion Across the Entire Chain

Summary Part 1

In the first part of this report, the implementation of the Intervention Mapping (IM) approach for Technology Promotion was examined, with a focus on systematically and methodically developing effective programs for Technology Promotion. The approach in this section follows the steps of IM, starting with the identification of influential behavioral and environmental factors, leading to initial recommendations for designing, implementing, and evaluating programs with the Technology Promotion Checklist.

For a successful application of the IM approach in Technology Promotion, a programmatic approach is essential, firmly anchored in the principles of IM. These principles provide concrete tools for developing an implementation process. However, this approach requires a significant shift in working methods for both developers and policymakers. A major challenge in this regard is the need for a thorough, methodologically, and scientifically sound approach, while there is simultaneous pressure to deliver quick and visible results.

To facilitate the implementation of the Technology Promotion Checklist, it is recommended to create accessible training and professional development opportunities for developers. This will assist them in applying the checklist and improve the quality of Technology Promotion programs. Additionally, it is crucial to establish a coordinated, sector-wide process to integrate the IM methodology with current practices. Developing standardized information and training materials can result in both cost savings and increased effectiveness.

Close collaboration between as many policymakers and funding parties in the Netherlands as possible is essential to set clear expectations for developers and enhance the impact of Technology Promotion. It is crucial for all stakeholders to be involved from the outset to effectively integrate the IM approach and achieve the intended behavioral changes and program objectives. This report provides a solid foundation for further discussion and planning with all relevant parties to sustainably improve the quality and effectiveness of Technology Promotion programs.

Background and Rationale

Shortage in the Technical Labor Market

Due to labor market shortages, there is a significant demand for ICT and technically skilled professionals in the Netherlands. The shortage of personnel in technology and ICT could hinder the energy transition, digitalization, and sustainability efforts, and negatively impact the country's competitive position (Rijksoverheid, 2023).

For technical professions, the labor market tension has risen from 'ample' in the first quarter of 2016 to 'very tight' starting in 2021 and continuing to the present (UWV, 2023a). Despite numerous efforts to increase the workforce in the sector, there were 82,800 vacancies for technical professions in the second quarter of 2023, according to data from the UWV (2023b). For ICT professions, the tension indicator has remained 'very tight' since 2017 (UWV, 2023a), with 28,750 vacancies in the second quarter of 2023 (UWV, 2023b).

To meet the growing demand for ICT and technically skilled personnel (hereafter referred to interchangeably as ‘technical professions,’ ‘technical personnel,’ or ‘technical education’), efforts are being made to address the 'leaky STEM pipeline.' A significant portion of students who choose a STEM/technical path at some point in their educational trajectory ultimately do not graduate with a professional diploma in the technical sector (Langen & Meelissen, 2019; see Figure 1).

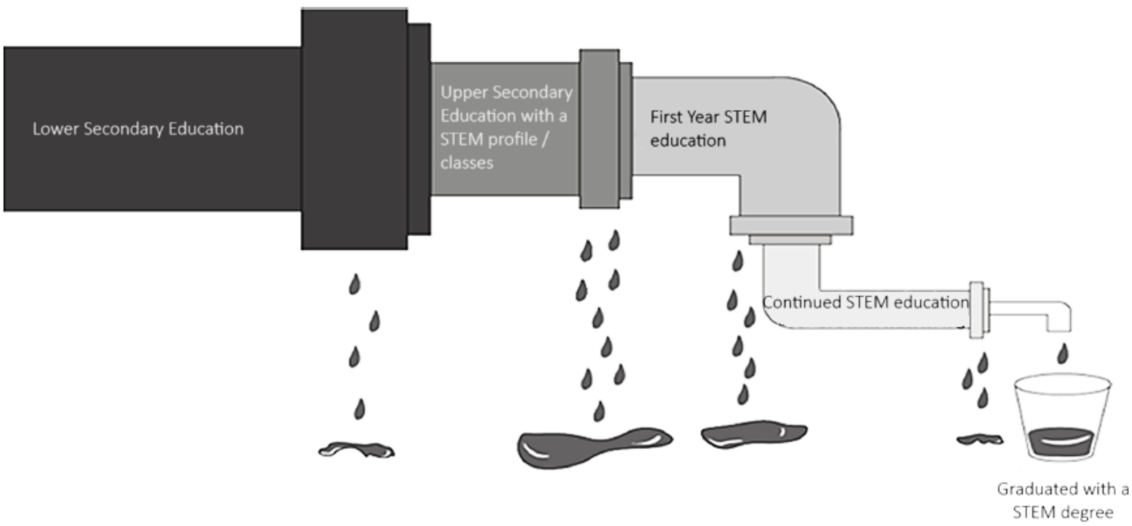

Figure 1. The Leaky STEM/Technical Pipeline. Source: Langen & Meelissen (2019)

Langen and Meelissen (2019) inventoried the extent and reasons for this leakage in the Netherlands at multiple key moments, among other things by examining data from the TIMSS and PISA from 2015. Throughout their school trajectory, students develop specific ideas early on about the content of technical education and professions. These perceptions subsequently determine the extent to which they are interested in pursuing a technical education later on. Additionally, girls in the Netherlands (more than in other countries) already show less self-efficacy in STEM/technical subjects at the age of 10 compared to boys, even when they score equally on tests. An investment in future technical personnel thus begins with investing in the beliefs of children from an early age, continuing until they enter the workforce.

Investments in Technology Promotion

In the Netherlands, many public-private partnerships (PPSs) are actively working to introduce children in primary education and young people in secondary education to technology (Techkwadraat, n.d.). The government encourages initiatives to "repair the leaking pipeline" through various subsidies.

Through Sterk Techniekonderwijs (STO), schools and businesses in the region collaborate to give all vocational secondary education (VMBO) students an introduction to technology. Between 2020 and 2024, this collaboration was established between VMBO, secondary vocational education (MBO), and businesses. The subsidy is being extended from 2025 to 2029, with a broader focus to include primary education in the collaboration (Ministry of Education, Culture, and Science, 2024). Approximately €390 million will be allocated under the STO scheme for the 2025–2029 period, with a minimum of 10% of the eligible portion requiring co-financing from one or more companies (DUS-I, n.d.-a).

The Techkwadraat proposal, partially overlapping with the STO scheme, aims to expose all children and young people in primary and secondary education to the opportunities of science, technology, and ICT. The project requires an investment of €502 million, comprising €70 million from regional contributions, an in-kind contribution from the business sector estimated at €80 million, and a contribution from the Growth Fund (Platform Talent voor Technologie, n.d.). The National Growth Fund is investing up to €351.6 million, including €145.8 million granted and a conditional allocation of €205.8 million (National Growth Fund, n.d.-a).

The Impuls Open Leermateriaal (IOL) subsidy supports collaboration between schools, educational, and expertise organizations to develop and utilize open educational materials. This project has been allocated €20.5 million from the National Growth Fund until 2024, with a further €57.5 million conditionally allocated until 2030 (National Growth Fund, n.d.-b). A portion of this budget is used to develop technology lessons.

In addition to these subsidies aimed at addressing the early "leakage" of technical potential, the government is also allocating funds specifically for collaboration between vocational education and employers. In 2023, an amount of €123 million was allocated, supplemented by €97 million from businesses, education institutions, and provinces. This helps bridge part of the gap between vocational education and the labor market for jobs that contribute to the digital and energy transition.

The business sector and training and development funds (O&O funds) contribute co-financing to some of the above-mentioned national initiatives. In addition, parties in the technical sector agree on Training and Development Collective Labor Agreements (O&O-CAOs) (Vakraad Metaal&Techniek, n.d.). The O&O funds use the money available to them not only for training existing personnel but also for initiatives to engage children and young people in technology (Wij Techniek, n.d.).

The Need for Control Over Investments

Despite the substantial number of organizations and networks active in the Netherlands promoting STEM, the growth of the workforce in this sector has not kept pace with the increasing demand for technical personnel. Over the past decades, significant investments have been made to increase the "technical workforce of the future" across primary, secondary, and vocational education. Now, substantial funding is being made available again, and the need for visible effects on the labor market is becoming more urgent.

However, an increase in available financial resources does not necessarily mean this should translate into more (numerous) initiatives. In recent years, the foundation for impactful technology promotion has been laid by organizing regional collaborations. Now that this important groundwork has been established, there is a growing need not only to develop more initiatives but to invest in impactful and effective ones. Some key reasons for this include:

- Efforts to promote technology can have not only a positive or neutral effect on children and young people but also a negative one. In an international literature review conducted as part of this research, one Dutch study was included. This study showed that company visits resulted in a significantly negative effect, with children finding technology less enjoyable after the visits compared to before (Post & Walma, 2014). Therefore, a careful selection of initiatives based on effectiveness is crucial.
- Schools are the most common channel to reach children and young people, whether through lessons, organizing technology-related outings, or company visits. Time in schools is limited, underscoring the importance of selecting the most impactful initiatives. Ideally, schools should choose only options that have a (maximum) positive impact.
- Although significant funding is available now and will continue to be in the coming years, there remains much work to combat persistent negative perceptions of working in technology. Therefore, a cost-efficient approach is still essential.

A portion of the Social Partners and O&O funds in the technical sector (hereafter referred to as the “Steering Committee”) have joined forces to use the Technology Promotion Research Report to begin answering a common question: "Are there both content-related and process-related ways to make Technology Promotion programs more impactful and cost-efficient?"

The search focused on finding a way to:

1. Create a shared understanding of what "impactful Technology Promotion" entails and identify the conditions ("predictors") that indicate impactful Technology Promotion initiatives.
2. Use this understanding as a framework for decision-making processes.
3. Initiate a learning system by stimulating a continuous process of developing, evaluating (and, where necessary, reforming) activities.

The Intervention Mapping (IM) method is already known nationally and internationally for developing, implementing, and evaluating interventions (i.e., initiatives, programs, activities). The application of Intervention Mapping has proven to lead to more effective interventions, especially in the healthcare sector (O’Cathain et al., 2019, Peter, Bruin & Crutzen, 2015). The methodology bridges the gap between science and practice, offering a clear step-by-step plan for developing interventions. The following chapters in Part 1 of this report provide an initial exploration of how the Intervention Mapping method can be applied to Technology Promotion and what is required for its successful implementation.

Intervention Mapping for Technology Promotion

Intervention Mapping in Brief

The Intervention Mapping (IM) approach outlines the iterative path from problem identification to solution or mitigation. This planning method is grounded in theory and evidence, incorporating environmental influences when assessing and addressing behavioral issues, as well as encouraging community participation (Bartholomew Eldredge et al., 2016).

In simple terms, applying Intervention Mapping involves working through six steps, starting from the question, "What is the problem?" to "What is a possible solution?" and finally, "Did the solution actually solve or reduce the problem?" Figure 2 outlines the six planning steps and two operational steps (implementation and evaluation). Each of the six IM steps involves multiple tasks that integrate theory and evidence (see Figure 3 on the next page for sub-steps focused on health-promoting programs). Completing the tasks in one step generates a product that guides the next step. In this way, each step builds on the previous one's findings.

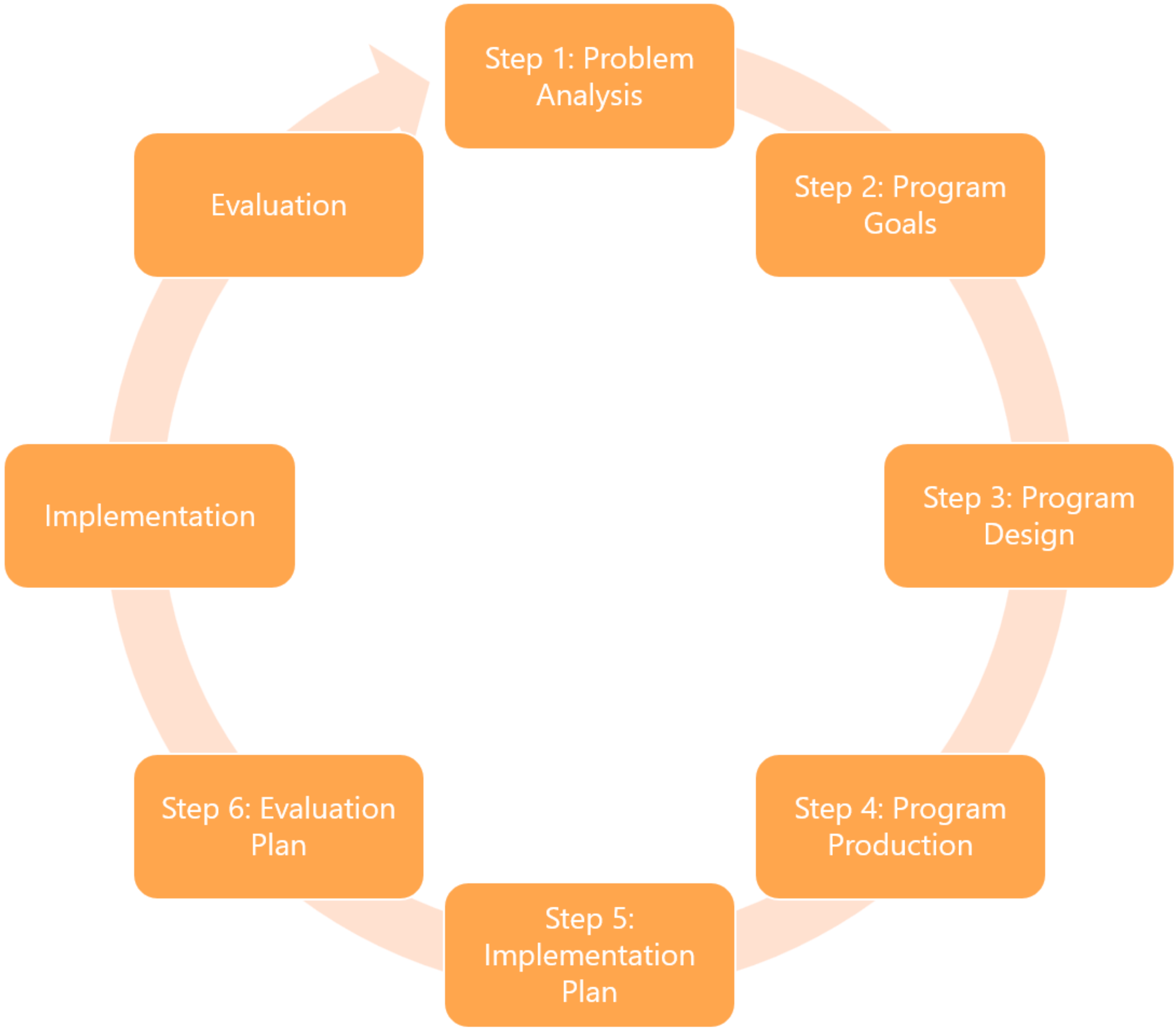

Figure 2. The basic steps of Intervention Mapping

Following all the steps serves as a blueprint for designing, implementing, and evaluating an intervention based on theoretical, empirical, and practical information. The key elements in Intervention Mapping (IM) are planning, research, and theory.

The book *Planning Health Promotion Programs: An Intervention Mapping Approach*, which details the IM methodology, delves into the procedures for planning activities and provides technical assistance for identifying theory-based determinants and matching them with appropriate methods for change (Bartholomew Eldredge et al., 2016).

Evaluation	Step 1 Needs assessment	• Establish a participatory planning group • Conduct the needs assessment • Assess community capacity • Specify program goals for health and quality of life
	Step 2 Matrices	• State outcomes for behavior and environmental change • State performance objectives • Select important and changeable determinants • Create a matrix of change objectives
	Step 3 Theory- based intervention methods and practical applications	• Generate program ideas with the planning group • Identify theoretical methods • Choose program methods • Select or design practical applications • Ensure that applications address change objectives.
	Step 4 Intervention program	• Consult intended participants and implementers • Create program themes, scope, sequence, and material list • Prepare design documents • Review available program material • Draft program material and protocols • Pretest program materials and protocols • Produce materials and protocols
	Step 5 Adoption and implementation	• Identify potential adopters and implementers • Reevaluate the planning group • State program use outcomes and performance objectives • Specify determinants for adoption and implementation • Create a matrix of change objectives • Select methods and practical applications • Design intervention for adoption and implementation
Implementation	Step 6 Evaluation plan	• Review the program logic model • Write effect evaluation questions • Write evaluation questions for changes in the determinants • Write process evaluation questions • Develop indicators and measures • Specify evaluation design

Figure 3. Intervention Mapping Steps Including Sub-Steps for Health Promotion Programs

Technology Promotion is typically focused on inspiring children and young people to avoid dismissing the idea of a career in technology at an early age. To effectively influence career choice behavior, it is essential that initiatives are grounded in behavioral science theory and research. Behavioral science knowledge is integrated into each of the six steps of Intervention Mapping (IM). In theory, this method is perfectly applicable in the field of Technology Promotion. There are numerous examples where Intervention Mapping has been used to develop scientific intervention studies (Bartholomew Eldredge et al., 2016, pp. 34-38). However, to apply it in the technology sector, it is important to recognize the differences between the world of technology and that of scientific research and healthcare, and where necessary, adapt the methodology to suit this new context.

The Translation of the IM Methodology for Technology Promotion

To effectively apply the Intervention Mapping (IM) methodology to make technology promotion initiatives more impactful, it is crucial to recognize that various parties, with dissimilar roles and mandates, are involved in the process of selecting, designing, and evaluating initiatives. The following classification can be made:

1. Policy Makers/Financing Parties: These are organizations, sometimes collaborating in consortia or coalitions, which initiate the development of a program or activity. Their tasks include:
    a. Conducting a (global) problem analysis to determine which issue should be addressed through a program or activity.
    b. Developing a framework of criteria that newly developed programs and activities must meet. For instance, policy makers may require that a behavioral expert and program implementers be involved in program development, or that a newly created activity be evaluated in a pilot program for effectiveness before being implemented on a large scale.
    c. Setting practical boundaries for the development of programs and activities, such as maximum budget limits or time restrictions on the staff's involvement in promotional activities.
2. Developers: The broad task from policy makers and financing parties is typically assigned to one or more developers who turn the policy frameworks into practical solutions. These developers work within the boundaries set by the policy makers. The group may or may not include those who will implement the program (e.g., teachers).
3. Implementers: In larger initiatives, such as national programs, it is often not possible to involve all implementers in program development. Ideally, a representative group of implementers is engaged early in the decision-making process. However, a large portion of implementers will inevitably be informed only after the program has been developed. Implementers receive a detailed program description and deliver the content to the target group. In the context of technology promotion, implementers could be teachers, parents, or employees from companies that host visits.
4. Target Group: The group whose behavior is intended to change; in this case, children in primary education and young people in secondary education.

This layered structure reveals the first major challenge. In scientific research, the IM steps are typically conducted by the same group of people. This group is often made up of experts from the field (e.g., behavioral or health experts) and representatives of key stakeholders (policy makers, implementers, and the target group). They decide collectively to use the IM methodology to develop a program, going through the six steps of Intervention Mapping together, maintaining control and oversight from start to finish.

Intervention Mapping for Policy Makers and Financing Parties

Policy Makers in the Technical Sector, such as those responsible for leading subsidies, play a significant role in overseeing parts of the Intervention Mapping (IM) steps. They are able to conduct a thorough problem analysis (step 1) and clearly define the objectives that need to be achieved (step 2) in the assignments they provide to developers. The level of detail in which these steps are worked out depends on how many “layers” have been incorporated into the decision-making process, from problem analysis to problem mitigation. The setup of the Sterk Techniekonderwijs (STO) program provides an example of how these layers are structured in large-scale national initiatives (see figure 4, adapted from van den Berg et al., 2020, and Sterk Techniekonderwijs, 2019).

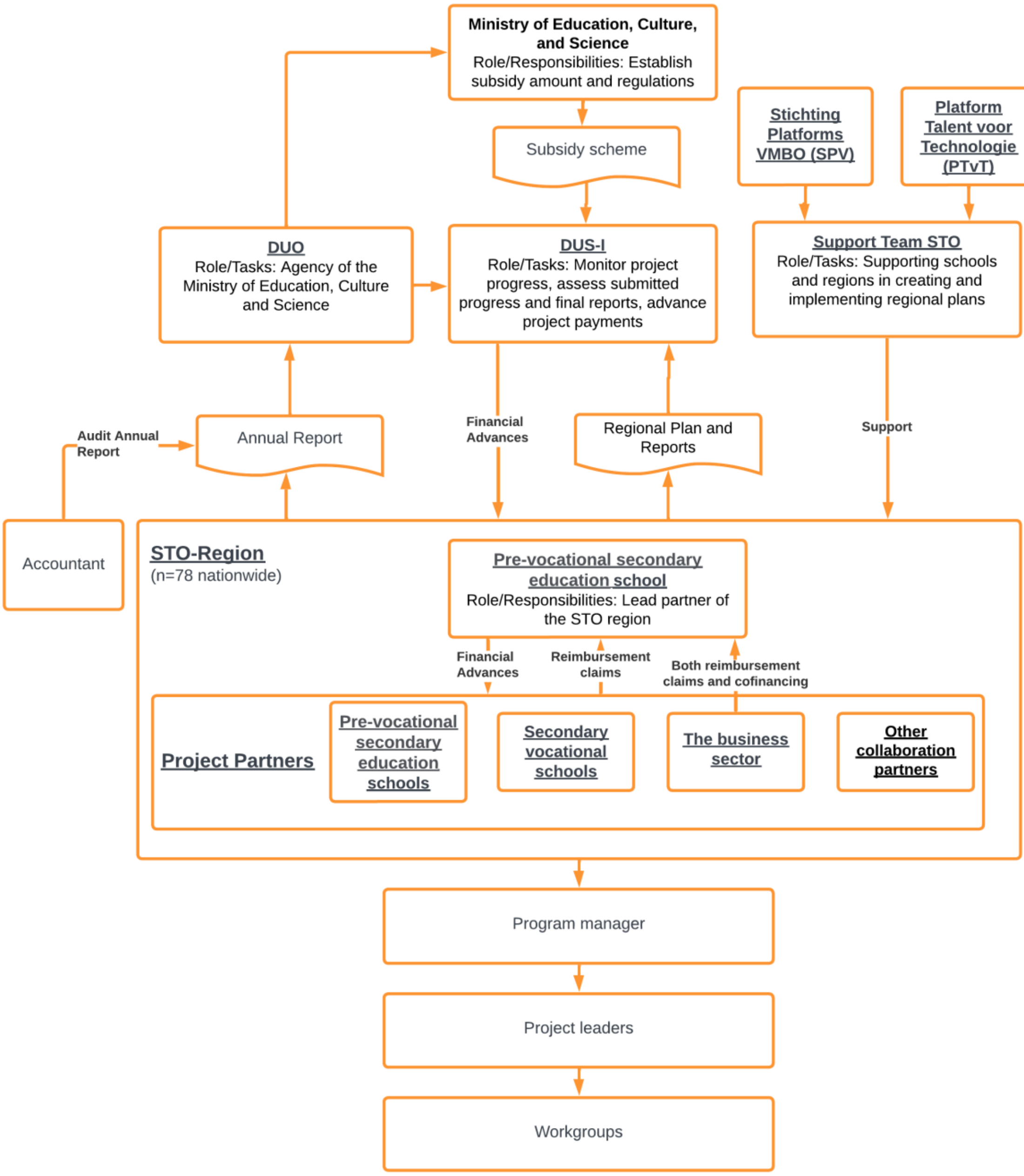

Figure 4. Organizational Structure of Sterk Techniekonderwijs (STO)

In the organizational structure of the STO (Sterk Techniekonderwijs), the problem analysis and determination of possible program goals at the national level will likely be conducted by the subsidy provider (potentially supported in this analysis by other institutions). This initial information helps establish that a subsidy is necessary and beneficial. It also allows for informed decisions regarding the frameworks included in the subsidy scheme. STO regions will then supplement the problem analysis and further refine program goals based on regional differences. Thus, they concretize steps 1 and 2.

For steps 3 through 5, STO regions delegate control to developers. These layers in the STO organizational structure are evident through program managers, project leaders, and working groups. Developers are responsible for these steps on behalf of policymakers (the STO region).

Although policymakers do not write the programs themselves, they can still encourage developers to apply the IM methodology in the program development process in many ways. This can be done in either a more flexible or more directive manner. There are several examples within the Dutch context that demonstrate this.

Promoting the Methodology: The RIVM Example

To encourage developers to work more methodically in a non-mandatory way, policymakers can share success stories from the sector. The National Institute for Public Health and the Environment (RIVM), part of the Ministry of Health, Welfare, and Sport, recommends the IM methodology as the structured approach to be used in intervention development (Loketgezondleven.nl, n.d.-a).

On its website Loket Gezond Leven, the RIVM shares several success stories. For example, the IM methodology was used in the development of the lesson plan "Lang Leve de Liefde," which has been taught in schools for many years. The RIVM reports that students who received education through the current materials of Lang Leve de Liefde, compared to those who received standard education, knew more about AIDS (Acquired Immune Deficiency Syndrome) and STDs. They also had more confidence in their ability to use condoms and were more likely to plan to do so in the future. The conclusion drawn is that "*In a previous version of the lesson plan [of the Lang Leve de Liefde methodology], this structured approach was not applied, and research shows that the now methodically developed materials are more effective than the previous version*" (Loketgezondleven.nl, n.d.-b).

Sharing Accessible Instructional Materials: The TNO Example

The Netherlands Organization for Applied Scientific Research (TNO) has translated the IM principles into the *Keuzewijzer Gedragsinterventies Veilig en Gezond Werken* (Huijs et al., n.d.). This online tool helps in developing an effective behavioral approach by using existing behavioral insights and knowledge about effective elements of interventions. The *Keuzewijzer* outlines the steps necessary for a behavioral approach across three different occupational health themes: mental health, physical workload, and occupational safety (Bakhuys Roozeboom, Bouwens, 2024).

The *Keuzewijzer* translates key theories from the book *Planning Health Promotion Programs: An Intervention Mapping Approach* into a compact and easy-to-follow step-by-step guide. It also includes multiple examples, which are elaborated for each step. This makes the tool universally accessible, even for developers who do not have an academic background or the ability to study Bartholomew Eldredge et al.'s (2016) book in-depth. However, TNO advises involving behavioral experts when using the *Keuzewijzer*. Developers can contact TNO for expert guidance during the process.

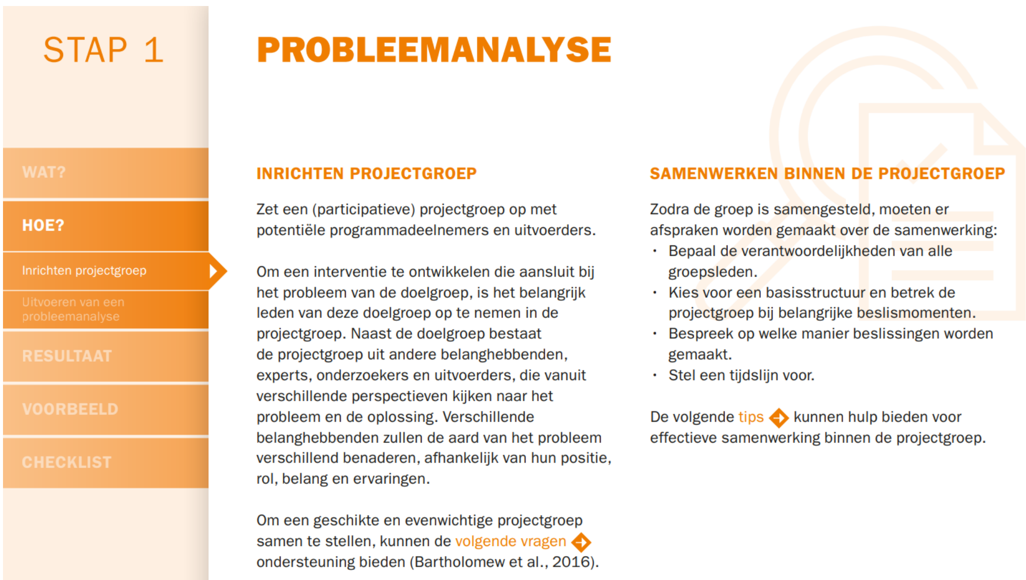

Figure 5. Step 1 from the TNO Guide for Behavioral Interventions for Safe and Healthy Work: Problem Analysis

Making the Use of the IM Method Profitable: Example from CROW

In the Netherlands, the Intervention Mapping (IM) method has been applied for ten years in the qualitative assessment of traffic education materials (Hukker et al., 2016). In 2012, a traffic education checklist was developed, commissioned by CROW, to provide more insight into the quality of traffic education programs (Vissers, 2010 & Vissers, 2012). This checklist helps assess ten essential development steps to determine whether traffic education programs are responsibly designed and meet certain quality standards. The checklist's evaluation criteria not only clarify whether the assessed program aims for certain goals but also whether the correct didactic approach is used to achieve those goals and whether steps are taken to ensure the quality of the developed product (Vissers et al., 2023).

Developers can register with CROW, and information about their program, including the checklist score, is added to the Knowledge Catalog (*Kenniscatalogus*) (Toolkit Verkeerseducatie, n.d.). Schools and municipalities can use this website to make informed decisions about which programs to purchase to cover the traffic education theme. This demonstrates how applying the IM method benefits the developer as well.

Ten years later, this checklist is still in use; currently, 151 programs are listed in CROW's online Knowledge Catalog, 124 of which have been assessed (Toolkit Verkeerseducatie, n.d.).

Like TNO, CROW also provides accessible instructional materials. They have created:

- A comprehensive manual for the Traffic Education Checklist (Vissers et al., 2019).
- A "Learning Objectives Document," outlining the necessary knowledge, skills, and attitudes required for various target groups to participate safely in traffic (Vissers & Hukker, n.d.).
- Tips to promote effective evaluations (CROW, 2015).
- Several micro-learning videos available on YouTube (CROW [CROW Ede], 2023).

Once developers have created a program, they also receive feedback from two independent assessors who are experts in using the Traffic Education Checklist. After receiving feedback, developers can adjust their program as needed before the final evaluation is conducted.

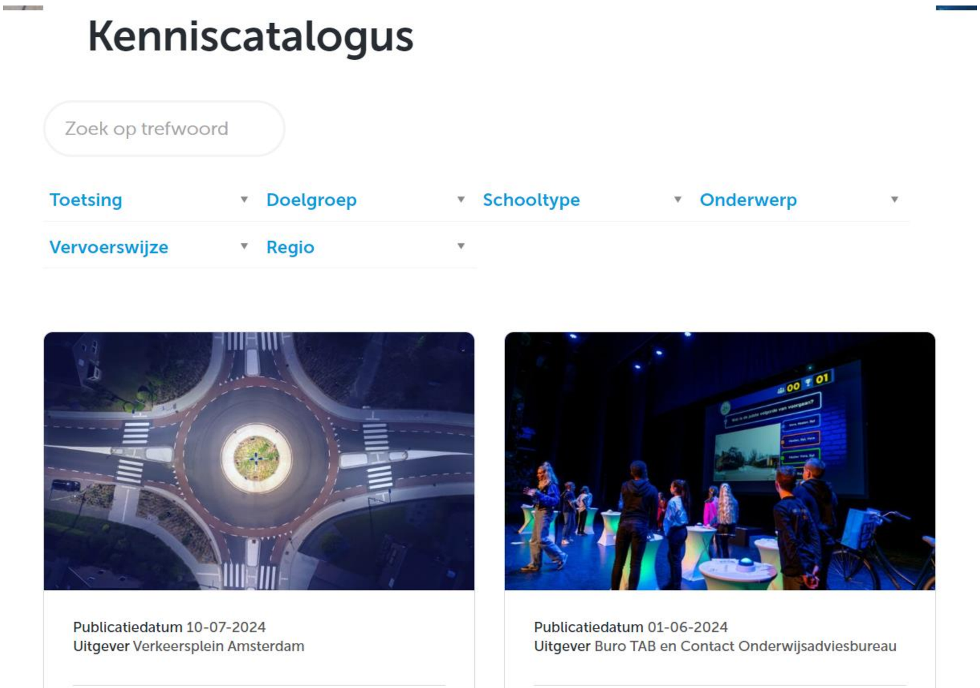

Figure 6. CROW Knowledge Catalog Including Traffic Education Programs

Intervention Mapping as a Condition for Funding: Example from the Province of Noord-Holland

In all the aforementioned examples, developers are encouraged to use the IM-methodology, but funding is still possible even if the developer chooses not to do so. However, in 2024, the Province of Noord-Holland decided once again to make evaluation of activities using the previously mentioned CROW Traffic Education Checklist mandatory under the "Uitvoeringsregeling subsidie verkeerseducatie scholieren Noord-Holland" (Provincial Government, 2023). The score obtained during the evaluation has a direct impact on funding if the subsidy cap is reached. Some of the stipulations include:

Article 3 […]:

2. The activities mentioned in the first paragraph must:
    a. be included in the CROW Traffic Education Toolkit and evaluated by CROW; and
    b. be implemented as described in the CROW Traffic Education Toolkit regarding the methodology and target group.

Article 4

A subsidy application must be submitted using a form provided by the Provincial Executive and must at least include:

a. the name of the educational project as listed in the CROW Traffic Education Toolkit;
b. a mention of the score (stars) as listed in the CROW Traffic Education Toolkit;

[…]

Article 7

1. If the subsidy cap is reached, applications eligible for subsidy will be ranked on a priority list.
2. The ranking will be determined by the number of points (stars) listed in the CROW Traffic Education Toolkit as of February 13, 2024, with a maximum of 50 points.
3. Applications will be honored in order of highest to lowest on the priority list.

This way, the province not only maintains control over the quality of programs it funds, but it also simplifies the decision-making process when the subsidy cap is exceeded. Developers are aware in advance of how to maximize their chances of funding, which allows them to actively work toward that goal. This clarity and transparency contribute to an increase in quality across the entire chain.

Conclusions for Policymakers

It is clear from the examples above that policymakers have a major influence on the working methods of developers. Policy largely defines the playing field on which other stakeholders play the game. The earlier the rules are shared, and the clearer they are to follow, the better (and even more enjoyable) the game becomes.

Policymakers are therefore the first to act in making future programs more methodologically robust and impactful. They can achieve this in several concrete ways, including:

1. When policymakers agree that there is a desire to make programs more methodologically sound and evidence-based (informed by theory and research);
2. Integrating the IM-methodology in the support offered to developers in various ways. In the example of STO, for instance, it could be envisioned that the STO support team shares information and aids STO regions to integrate the IM methodology into regional plans. For developers (program managers, project leaders, and working groups), the STO support team could also provide information and assistance.
   NB: When developing training and information materials regarding the IM-methodology, it is important to apply the IM steps again. Policymakers (STO regions) and developers represent

different target groups, for which various parts of the IM-methodology are relevant, and different channels to convey information are appropriate.

3. Policymakers can choose to link consequences to the use or non-use of methodological frameworks and (scientific) evidence by developers. These can be both positive consequences, such as increasing the visibility of higher-quality programs, and negative consequences, such as not funding programs that do not meet a minimum quality standard.
4. It is crucial to apply the IM methodology across the entire network. The goal is not only to make the last step (program development) more methodologically sound but to strengthen the entire process. When the initial problem analysis is formed without (scientific) evidence or when a subsidy regulation is created without requiring a methodological and evidence-based approach, it becomes more difficult to ensure that the next party working with this information adheres to the IM methodology. However, with the proper application of training and information opportunities, this is possible.
5. For step 6, the evaluation, national initiatives may consider conducting cross-regional research through national research institutions, such as the *Nationaal Regieorgaan Onderwijsonderzoek* (NRO). To monitor the effectiveness of regional activities, it may also be considered to determine nationwide which questionnaires are used before and after activities to allow comparisons between activities in terms of effectiveness. Additionally, it could be considered to centralize and analyze regional research results (data).

For all steps, it is essential to speak the same "language." In other words: what is quality? By concretizing this, it becomes easier to clearly communicate to developers what is expected of them. As part of translating Intervention Mapping for Technology Promotion, a start has been made with the Technology Promotion Checklist, which fits the role and tasks of the developer.

Intervention Mapping for Developers

To enable the application of IM in the technology sector, it is essential to develop a clear method through which programs within the framework of Technology Promotion can operate from the perspective of the IM approach. To provide policymakers and funding parties with insight into whether developers are working according to the IM approach, an evaluation method is proposed. This method utilizes a checklist comprising ten steps to assess the quality of initiatives related to Technology Promotion. The ten steps and corresponding tasks provide an accessible way to check whether the basic principles of the IM approach have been followed. Ideally, developers would review this checklist before developing a program to create the program based on it. However, it is equally possible to apply the checklist to existing programs, further developing, or adjusting them as needed. The goal is to determine whether Technology Promotion programs have been designed and developed in a structured and substantiated manner and whether they meet established quality standards.

The method overlaps with the checklist and accompanying instructions developed by Hukker et al. (2016) in the context of traffic education. The need to set up a process to evaluate traffic education programs arose from a need of regional coordinators, similar to the current policymakers' need to better coordinate activities and learn more from each other's experiences. In 2012, a traffic education checklist was developed to provide more insight into the quality of traffic education programs (Vissers, 2010 & Vissers, 2012). The checklist was supplemented based on other illustrative examples of the IM application in various sectors and the literature review conducted for the current assignment (see part 2 of the Technology Promotion Research Report).

The implementation of the Technology Promotion checklist is, in itself, an intervention. To optimize the effectiveness of Technology Promotion, an Intervention Mapping approach can also serve as the foundation. After all, implementing the checklist requires a behavioral change among developers, and effective implementation requires, among other things, training on how to use the checklist and removing barriers to its use. This part of the report covers two main components in this regard:

1. Technology Promotion Checklist

Developing a protocol to assess existing and future programs aimed at Technology Promotion based on the six steps described in the Intervention Mapping protocol. This resulted in the Technology Promotion Checklist.

2. Intervention Mapping for the Implementation of the Technology Promotion Checklist

Policymakers need to take several steps and actions to ensure the successful implementation of the Technology Promotion Checklist. This set of steps and actions can be viewed as an intervention. Therefore, it is appropriate to apply the Intervention Mapping approach here as well (Fernandez et al., 2019). Following these steps makes it clear to both policymakers and developers why a Technology Promotion Checklist is an appropriate intervention for strengthening the scientific basis of Technology Promotion interventions.

Technology Promotion Checklist

Using the Technology Promotion Checklist, it is possible to evaluate whether programs have been responsibly designed and developed by assessing ten essential development steps, and whether they meet certain quality requirements. Through the checklist's evaluation criteria, it becomes clear whether the assessed program pursues specific goals, and whether the appropriate didactic approach is employed to achieve those goals, as well as whether steps have been taken to ensure the quality of the developed product.

The application of Intervention Mapping in the Verkeerseducatie Toolkit (Hukker et al., 2016) serves as a solid foundation and has been used as a blueprint for the Technology Promotion Checklist. In the adaptation from Verkeerseducatie to Technology Promotion, several steps that were specific to Verkeerseducatie were either removed or modified to align with the quality criteria that support the creation of effective Technology Promotion programs. The table below provides a complete overview of the steps and criteria per step, which form the content of the Technology Promotion Checklist.

Technology Promotion Checklist	
Step 1: Selection of the behavior to influence	
	Is the behavior to be influenced clearly described? (e.g., interest in a technical career or choosing a technical profile in upper secondary education)
	Has an analysis been conducted of the factors that drive or determine the choice behavior?
	Is the analysis scientifically substantiated?
	Does the program target behavior or behavioral backgrounds that are proven to have a clear relationship with the choice behavior of young people?
Step 2: Selection of the target group	
	Does the program target a group that exhibits or may exhibit undesirable choice behavior?
	Can the target group be reached?
	Is the method for reaching the target group clearly described and justified?
	Are other parties (e.g., parents, teachers) involved in the program?
	Is the decision to involve other parties clearly described and justified?
Step 3: Objectives	
	Do the program's objectives align with the factors that promote behavior change?
	Are specific objectives formulated in terms of changing behavior?
	□ □ Are the objectives clearly and measurably described?
Step 4: Promotion principles	
	Are the applied promotion principles and methods justified and substantiated?
	Do the selected methods align with the stated objectives and described (lesson) situations?
	Does the program encourage active participation of the learners in the learning process?
	Does the program provide sufficient opportunities to customize the program to fit the target group and individual participants?
	Does the program address the integration of theory and practice?
	Does the program consider the impact of technology on societal issues?
	Does the program translate specific examples or settings to generalized applicability?
Step 5: Content and presentation of materials	
	Is the information in the program factually correct, up-to-date, complete, and well-documented?
	Is the content tailored to the target group's level?

	Is the content aligned with the target group's world of experience?
	Do the format and medium suit the target group?
	Are the design and layout appealing to the target group?
	Is there follow-up over time (e.g., refresher lesson)?
Step 6: Testing and evaluation within the program	
	Is it assessed or evaluated whether the learning objectives for participants are being achieved?
	Is the method of testing or evaluation described and justified?
	Are validated questionnaires used?
	Does the question format of the tests or evaluation sessions align with the level of the target group?
	Do the format and medium of the testing align with the target group?
Step 7: Manual and guide for program implementation	
	Is there a manual and guide available for the implementation of the program?
	Does the manual clearly describe and justify the objectives and activities of the program components?
Step 8: Program implementation	
	Is it clearly described who provides the resources to implement the program and how these resources can be accessed?
	Does the manual or implementation plan provide recommendations for program implementation?
	Are there requirements formulated for trainers/teachers/guest speakers who will deliver the program?
	If trainers/teachers/parents lack the required skills to effectively deliver the program, are there training opportunities available?
	For guest speakers: Is the chosen speaker a suitable role model for the target group?
	Is the manual clear about the parties/organizations needed for the program's execution and how to approach them?
	Does the program allow for customization at the "context level"?
Step 9: Process evaluation: collecting user experiences	
	Are user experiences of all involved parties (both young people and guest speakers, teachers, parents) actively gathered by the developers?
	Are user experiences used to further develop the program?
	Are costs and benefits analyzed in relation to each other to provide advice on continuation?
	Are feasibility, sustainability, and suitability considered when scaling the program beyond the current setting
	Are user experiences, cost-benefit analyses, and scalability considered in the recommendation to continue the program?
Step 10: Effect measurement: monitoring and evaluation of overall effects	
	Are the effects of the program monitored?
	Is it clearly described who is responsible for program follow-up over time?
	Is the program adjusted based on the monitoring results?

Evaluation Using the Technology Promotion Checklist

The score derived from evaluating the checklist corresponds to that of Godin et al. (2007). Per criterion, evaluators can determine, based on the documents provided by developers, whether the criterion is not addressed, insufficiently addressed, somewhat addressed, or well addressed. When at least half of the criteria of a step are assessed as somewhat or well addressed, the step as a whole is rated as "Sufficient". If a total score of six or more steps are rated "Sufficient," the overall score for the program is also considered "Sufficient".

Additional Suggestions for Further Development of the Technology Promotion Checklist

In developing the Technology Promotion Checklist, as outlined in the table above, feasibility for developers in the technology sector was a key consideration. Moreover, it may be worthwhile to expand or adjust the checklist with more critical checks as the quality of programs evaluated using the Technology Promotion Checklist improves. The following suggestions could then be considered.

Differentiation Between Quality and Effectiveness Meeting

Meeting quality standards as described by IM increases the likelihood that a project or program will achieve the desired effect. However, the checklist does not assess effectiveness. Therefore, it is possible in theory that a project meets all quality standards but does not show the desired effect.

It may be worth considering the possibility of providing information on effectiveness, in addition to quality, if available. Brug et al. (2010) combined the IM approach with the framework for the design and evaluation of complex interventions for health improvement from the UK Medical Research Council (Campbell et al., 2000), resulting in four recognition levels for programs:

1. Theoretically grounded;
2. Plausibly effective;
3. Proven effective;
4. Proven cost-effective.

Each higher recognition level includes the requirements of the preceding level. For more details on the criteria for each recognition level, see Brug et al. (2010). This methodology was adopted by the Dutch National Institute for Public Health and the Environment (RIVM), although the recognition levels are not fully aligned with the four levels mentioned above (Loketgezondleven.nl, n.d.-c). Currently, the following levels are recognized:

0. Well described;
1. Well substantiated;
2. Initial evidence of effectiveness;
3. Good evidence of effectiveness;
4. Strong evidence of effectiveness.

Measuring Effectiveness

In a reflection on the use of the Traffic Education Checklist, Vissers et al. (2023) noted that the assessment criteria for step 10, the effectiveness measurement, were adjusted during the ten years of checklist use. *"Initially, step 10 was mainly intended to encourage the execution of an effectiveness measurement. It examined whether the effects of a program were monitored and whether the outcomes were used to adjust the program. Simple, producer-conducted evaluations also received good scores."* In a revision of the Traffic Education Checklist, additional criteria were added to this step, such as: "*The measurement instrument is reliable and valid"* and *"A scientific study has been conducted; the measurement is designed with an experimental control condition and a pre- and post-test."*

These higher requirements can pose challenges, especially for small research groups or independent developers, as noted by Vissers et al. (2023). This is primarily due to the financial and work burden, for example, organizing control groups. Brug et al. (2010) also identified this risk. They also noted that the type of effect evaluation they promoted might favor programs targeting individuals or defined groups over those with a more integrated approach combined with a policy approach, as the latter is complex to evaluate, requires long-term follow-up, and is very costly.

Achieving statistical significance should not be the only measure of effectiveness in evaluating Technology Promotion. The lack of statistical significance may also be due to a small group size, a too-short follow-up time, or the response scale of the measurement instrument. For example, a minor change is easier to measure on a scale of 1 to 10 compared to a scale of 1 to 5. Additionally, in the context of Technology Promotion, where the decision-making moment is often further in the future, it is important to measure the effect both immediately after the program and after a longer period. Ideally, the goal is to achieve an effect that continues to impact the student over time.

Implementation of the Technology Promotion Checklist

The checklist alone is not sufficient to change the behavior of developers. To gain more insight into the underlying processes that are important to increase the success of the Technology Promotion Checklist, the following chapters explore steps 1 through 5 of Intervention Mapping to facilitate the checklist's implementation. This exploration is primarily based on desk research on developments in Technology Promotion in the Netherlands and the principles and underlying theory as described by Bartholomew Eldredge et al. (2016). Additionally, findings from part 2 of this report, meetings with the Regieraad, conversations with two researchers from Platform Talent voor Technologie, an interview with a Technology Promotion program developer, and the developers of the Traffic Education Checklist, Jan Vissers and Niki Hukker, have been important sources in this initial exploration of potential personal and environmental factors that may influence the implementation of the Technology Promotion Checklist. The elaboration of the IM steps for implementing the Technology Promotion Checklist aims to give policymakers and funding parties an initial understanding of what is needed to take the next step in organizing further collaboration for the implementation of the IM approach, and therefore the checklist, in the Technology Promotion field. This is a first draft and does not provide a complete or tested picture of all the necessary steps for successful implementation. The following steps must be further supplemented and adjusted, in collaboration with all key stakeholders, should the decision be made to proceed with the IM approach in the Technology Promotion field.

Step 1: Logic Model of the Problem

In the first step of Intervention Mapping, the problem behavior is defined and then described in terms of behavioral factors and environmental conditions that drive or facilitate the problem behavior. Central questions include: “What is the problem?”, “Who is affected by the problem?”, “What behavior causes the problem?”, and “Why do people exhibit this behavior?” (Bartholomew Eldredge et al., 2016).

Target Group

The checklist is intended for developers (also known as program makers): the professionals involved in developing and implementing programs for Technology Promotion.

Visual Representation of the Problem Logic Model

The PRECEDE model was used as a framework to visually represent the problem logic model (theory) (Glanz et al., 2015; Green & Kreuter, 2005) in Figure 7.

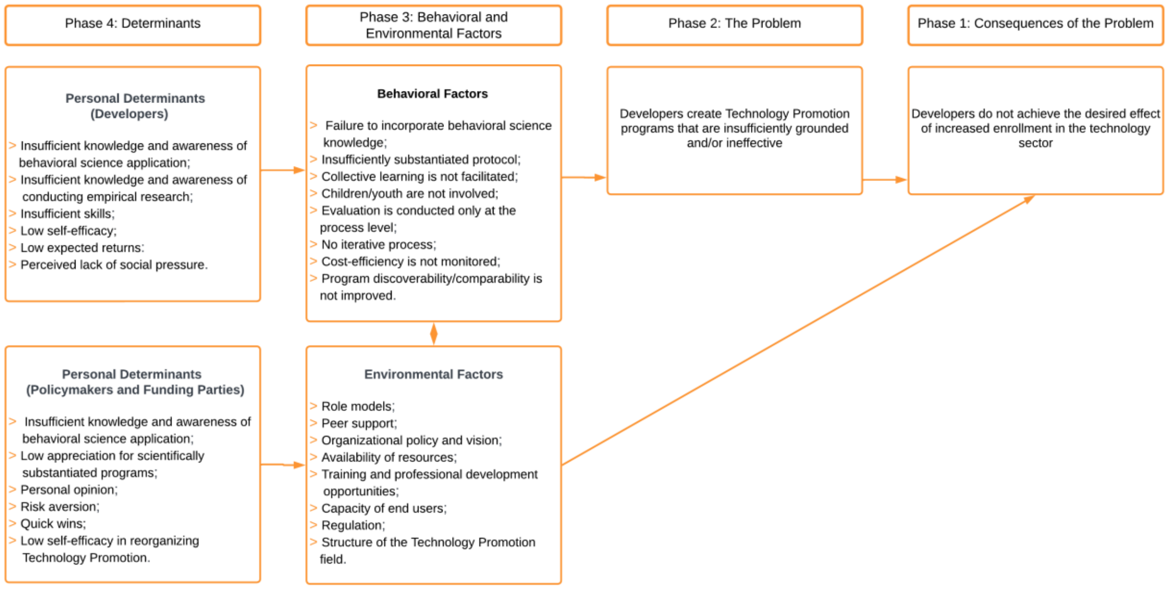

Figure 7. Problem Logic Model – Technology Promotion Program Formation

Phase 1: Consequences of the Problem

Following the order described by Bartholomew Eldredge et al. (2016), phase 1, which describes the consequences of the problem, is filled in after phase 2. The consequence of the problem behavior is described as “Developers do not achieve the desired effect of increased enrollment in the technology sector.”.

Phase 2: The Problem

In filling out the PRECEDE model, the starting point is to define the “problem”; phase 2 in Figure 7. In the case of the challenges experienced in advancing Technology Promotion, this can be described as “Developers create Technology Promotion programs that are insufficiently grounded and/or ineffective.” It is important to acknowledge that the group experiencing this behavior as problematic—the policymakers and funding parties—is not the group exhibiting the behavior.

Phase 3: Behavioral and Environmental Factors

The behavioral and environmental factors listed in phase 3 were brainstormed and are not exhaustive or evaluated. The brainstorm was informed by information from the literature review conducted for this assignment, meetings with the Regieraad, a Technology Promotion program developer, and the theoretical basis of Intervention Mapping.

Behavioral Factors

In this column, behaviors are listed that could increase the likelihood and impact of the problem: "Developers create Technology Promotion programs that are insufficiently substantiated and/or ineffective." These are split into factors over which the target group has direct influence and external factors — environmental factors — that influence the target group. Examples include:

- Failure to incorporate behavioral science knowledge: Knowledge, theories, and models from the fields of behavior explanation and change are either not or insufficiently incorporated into program design.
- Insufficiently substantiated protocol: Decisions in the program's design are not based on empirical research.

- Collective learning is not facilitated: Knowledge gained from developing one's own program is not shared with other developers.
- Children/youth are not involved: Children and young people are either not or insufficiently involved in the development of the program.
- Evaluation is conducted only at the process level: Evaluation does not occur, is of low quality, or is limited to the process level. An impact evaluation, assessing whether the program has affected the pre-set outcome, such as encouraging students to choose a science/technology track in high school, is not conducted.
- No iterative process: The program is not adjusted based on evaluations of process and outcomes.
- Cost-efficiency is not monitored: The decision to continue the program based on the balance between resources spent and results achieved is not made.
- Program discoverability/comparability is not improved: The developer does not make their program accessible on a platform where users can find and compare other Technology Promotion programs.

Environmental Factors

- Role models: The absence of (visible) role models who design Technology Promotion according to a methodologically and theoretically, empirically substantiated approach.
- Peer support: Lack of support from other developers, both inside and outside their own organization, to help the developer (learn) work according to the desired approach.
- Organizational policy and vision: If the organization's policy does not prioritize and value well-substantiated Technology Promotion programs, it does not encourage the use of the approach described in this report.
- Availability of resources: Limitations in financial and human resources required to further develop Technology Promotion programs using this novel approach.
- Training and professional development opportunities: If developers are not given enough opportunities to learn how to work according to the desired approach, it significantly increases the barrier to changing working methods.
- Capacity of end users: Users of Technology Promotion (such as schools) may not be willing to bear the additional burden (in terms of time or money) of participating in evaluation research.
- Regulation: Policymakers and other funding parties impose few or no requirements for evidence of program quality and effectiveness as conditions for funding.
- Structure of the Technology Promotion field: The funding for Technology Promotion comes from various channels, each with its own requirements regarding the substantiation and evaluation of developed programs. As a result, developers who are unwilling to develop their programs according to the IM approach may still conduct their insufficiently substantiated programs by obtaining subsidies or financial compensation through other channels.

Phase 4: Personal Determinants

The determinants mentioned in phase 4 are based on the same sources as phase 3, supplemented by eight key behavioral determinants, identified by five leading behavioral science theorists (Albert Bandura, Marshall Becker, Martin Fishbein, Frederick Kanter, and Harry Triandis). They distinguished the following key determinants as predictors of behavior:

1. The person has formed a strong positive intention or commitment to perform the behavior.
2. There are no environmental constraints that make it impossible to perform the behavior (*barriers*).
3. The person has the necessary skills to perform the behavior.
4. The person believes that the benefits of performing the behavior outweigh the costs (*instrumental attitude*).

5. The person experiences more social (normative) pressure to perform the behavior than not to (*perceived social norm*).
6. The person experiences that performing the behavior is more consistent than inconsistent with their self-image (*personal norm*).
7. The person's emotional reaction to performing the behavior is more positive than negative (*affective attitude*).
8. The person perceives they have the capacity to perform the behavior under varying circumstances (*self-efficacy*).

(Committee on Communication for Behavior Change in the 21st Century: Improving the Health of Diverse Populations, 2002; Fishbein et al., 2001; Montaño & Kasprzyk, 2015).

Personal determinants typically encompass cognitive factors and capacities. These include personal beliefs, knowledge, skills, and values. They are identified separately for the target group, in this case, developers, and the environment influencing them, including policymakers.

Developers

- Insufficient knowledge and awareness of behavioral science application: A lack of necessary knowledge and/or awareness of the added value of theories and models from the fields of behavior explanation and change.
- Insufficient knowledge and awareness of conducting empirical research: A lack of necessary knowledge and/or awareness of the added value of empirically substantiating the development of programs in the Technology Promotion field.
- Insufficient skills: Developers may lack various skills required to apply a methodologically and empirically substantiated approach, such as conducting literature reviews, organizing, and leading stakeholder discussions, or conducting valid process or impact evaluations.
- Low self-efficacy: Developers may feel they are not capable of conducting a more comprehensive and scientifically substantiated approach within the complex context or with limited resources.
- Low expected returns: Negative attitudes regarding the expected benefits of a more extensive approach relative to its drawbacks.
- Perceived lack of social pressure: Lack of (social) pressure to provide their programs with more comprehensive and scientific substantiation.

Policymakers and Funding Parties

- Insufficient knowledge and awareness of behavioral science application: Policymakers will not adjust their expectations towards developers regarding the incorporation of behavioral science insights if they lack the necessary knowledge or are unaware of the added value of these theories and models.
- Low appreciation for scientifically substantiated programs: In the field of Technology Promotion, the focus has traditionally been more on tangible and quick actions. Scientifically substantiating programs may take more time, leading to lower appreciation by policymakers.
- Personal opinion: Personal views and experiences can influence the direction and selection of Technology Promotion programs. For example, an employer with a strong relationship with a company that organizes field trips, or who enjoys building robots, may let these personal views influence program continuation decisions.
- Risk aversion: A new or innovative program might be seen as risky because outcomes are uncertain. Policymakers are accountable to stakeholders, and uncertainty can cause reluctance. Therefore, they may choose a familiar program with low returns over a new one with potentially higher but uncertain returns.

- Quick wins: Policymakers may prefer programs with quick, visible results at the process level. For example, installing a Technology Bus at a set number of schools is a visible and easily evaluated program at the process level.
- Low self-efficacy in reorganizing Technology Promotion: Reorganizing the Technology Promotion field to encourage developers to work in a new, desired way is complex. When individual policymakers and funders feel they lack the ability to achieve this, it can result in a "self-fulfilling prophecy." Policymakers' confidence in successfully restructuring Technology Promotion is crucial.

Influence of Determinants and Factors in Context

For both behavioral and environmental factors and determinants, the depiction provided in Figure 7 is not exhaustive. Additionally, the presence and strength of the relationship between individual determinants, factors, and the problem behavior have not been evaluated. The content of the logic model as outlined here should primarily serve as a starting point for discussions between developers, policymakers, and funders, and not as a complete representation of reality.

If the decision is made to implement the Technology Promotion Checklist, the influence of these determinants and behavioral factors must be assessed. The extent to which they affect the success of implementation will depend on the organizational context in which the Checklist is embedded, and the conditions set for its use. For example, it can be imagined that as pressure from policymakers and funders to substantiate and evaluate Technology Promotion initiatives increases, the level of flexibility for the program developer decreases. This would also reduce the degree to which "expected outcomes" influence whether a Technology Promotion program is methodologically substantiated and evaluated. If a more lenient approach is taken, the influence of this determinant will likely remain significant.

Step 2: Program Goals and the Logic Model of Change

Step 2 forms the foundation for the implementation of the Technology Promotion Checklist. In this step, it is specified who needs to do what to successfully implement the Technology Promotion Checklist.

In formulating desired outcomes, various perspectives can be applied. The perspectives described by Bartholomew Eldredge et al. (2016) can be applied in the context of Technology Promotion as follows:

1. Reducing Risk: An implementation plan focused on reducing the risk of Technology Promotion initiatives causing negative outcomes. For example, by avoiding a stereotypical company visit that reinforces traditional professional and gender roles.
2. Improving Technology Promotion: An implementation plan focused on better substantiating and evaluating existing Technology Promotion programs.
3. Strengthening Self-Management: An implementation plan focused on the active and iterative process of setting goals, choosing strategies, self-observation, and making informed decisions based on those observations.

Phase 1: Desired Outcome

The formulation for the desired outcome that results from the positive change of the problem behavior, as described in the Logic Model of the Problem (Figure 7), towards the target behavior and the positive change in environmental outcomes is: "Developers achieve the desired effect of increased enrollment in the technology sector."

Phase 2: Outcomes

To promote the implementation of IM through the introduction of the Technology Promotion Checklist, the following outcome or target behavior for developers can be formulated: "Developers

(re)design Technology Promotion programs based on well-considered, substantiated, and proven principles."
It has already been mentioned that the target group causing the problem, in this case, is not the group experiencing the consequences of the problem behavior. The group that primarily experiences this are policymakers and funding bodies. Fortunately, they also have the ability to (partially) influence the environmental factors related to the behavior of developers. For changes in developer behavior, a visible change in the behavior or outcomes of policymakers and funders is also needed. Key enabling outcomes for policymakers and funders may include:

1. Creating accessible, low-threshold training and professional development opportunities to enable developers to work according to the IM approach using the Technology Promotion Checklist.
2. Establishing a coordinated, sector-wide process for using the Technology Promotion Checklist that developers recognize and can follow.

If policymakers and funders choose to implement the IM approach, it is recommended to follow the IM steps for both outcomes to further develop them.

Conclusion and Further Recommendations

To successfully implement Intervention Mapping within organizations and national initiatives involved in Technology Promotion, policymakers and funders are the ones to take the first step. They determine the quality and shape of the final product by ensuring quality in the steps they execute (such as the problem analysis) and by involving all other stakeholders and individuals in the training and use of the IM methodology.

Using the Technology Promotion Checklist can help provide developers with clear expectations through a transparent and easily followed step-by-step plan. To implement the Technology Promotion Checklist, this implementation plan must be developed programmatically and in accordance with the principles of Intervention Mapping. Setting up a process to encourage developers to design programs based on well-considered, substantiated, and proven effective principles is complex, partly because:

- Working in the new way requires not only knowledge, skills, and conviction from developers but also from policymakers;
- Developers face different desires and requirements when designing programs from various policymakers, with policymakers being just one of them;
- There is a need for a more methodological, theoretically, and empirically substantiated approach to program development, which focuses on quality and effectiveness, as well as a demand for quick, tangible results, which has so far often led to a focus on process-level factors (such as the number of school visits to companies);
- The new way of working being asked of developers requires a new form of support, both financially and through the provision of training and information, which also necessitates a new form of collaboration between policymakers and funders.

Intervention Mapping provides some guidance in addressing this complex issue. Using Intervention Mapping as a framework brings transparency and direction to the workflow for everyone contributing to the development of the implementation plan for the Technology Promotion Checklist. To maximize impact, as many initiatives as possible should meet the conditions for impactful interventions. Therefore, it is strongly recommended to adopt the IM methodology as the innovative approach with as many important policymakers and funders as possible and, where possible, collaborate to implement Intervention Mapping in practice. From a pragmatic standpoint, a unified approach and collaboration make sense: developing training materials, support services, and information resources is costly. A collaborative approach is therefore also more cost-efficient.

It is advisable to take the next steps in implementing the IM methodology, as much as possible, in collaboration with key stakeholders in Technology Promotion.

Limitations

In the Intervention Mapping methodology, involving key stakeholders and those responsible for executing the project from the outset is central. In designing this section, only limited contact could be made between the researchers and the stakeholders. Most of the information has been obtained through public sources. The context in which the Technology Promotion Checklist may be embedded needs to be more thoroughly investigated to take the next step in implementing the Checklist within existing processes.

Part 2

Literature Review on Promoting a Choice for Technology Among Students (Aged 9 to 15)

Summary Part 2

This research highlights how self-efficacy, fear of failure, and objective performance in technology-related subjects influence students' choice of a technical school profile and career path. A literature review was conducted on national and international studies regarding the personal, environmental, and socio-demographic variables that influence the choice of a technical education or profession—referred to in the international literature as STEM (Science, Technology, Engineering, Mathematics)—among students in primary and lower secondary education.

The research shows that students with higher self-efficacy regarding their STEM skills have more interest in a STEM subject in upper secondary education, a STEM education, or a STEM career. A key caveat is that the focus is often on self-efficacy for mathematics, physics, or "science." This latter term may refer to chemistry or a combination of chemistry, physics, and biology. A specific study on the effect of higher self-efficacy in the subject of technology on the choice for STEM has not been conducted. However, one article did examine the effect of self-efficacy in mathematics and science specifically on students' interest in a future career in technology/engineering. This relationship was not found to be significant.

The level of "skill" is determined based on the objective score a student achieves in a STEM subject. Nearly all studies indicated a positive correlation between skill in a STEM subject and the choice for a STEM subject in upper secondary education or further education.

In addition to a student's skill in a subject, relative strength also plays a role. A student's relative strength is the subject in which they score the highest in relation to their scores in other subjects. A student with a relative strength in reading is more likely to choose further education in that direction, even if the score in a STEM subject is high enough for the student to qualify for a STEM track.

The study also emphasizes the importance of clear information about technical careers and the societal value of working in technology. Instrumental attitude, including the expectation of future career opportunities and rewards, positively contributes to young people's interest in a STEM career. Additionally, affective attitude, simply put, the enjoyment students experience in STEM lessons, has a positive influence on interest in STEM.

Notably, young people do not always mention parents or peers as direct sources of influence, although research shows that parents' education level and profession do play a role. Children of highly educated parents or parents with a technical profession are more likely to opt for a technical profile. A program where parents were informed about technology and subsequently recommended technology to their children significantly increased the likelihood that their child would choose a technical profile. Moreover, students who receive STEM support from parents are more often interested in a STEM career. No significant relationship was found between parents' socioeconomic status and the choice of a technical profile.

Peers at school also influence STEM choices. For example, the mathematical self-efficacy of classmates can positively influence boys' STEM expectations and negatively influence girls' expectations. Higher average self-efficacy in the class was associated with higher self-efficacy among boys, whereas self-efficacy among girls was lower. Additionally, research shows that when the average mathematical performance at a school is high, students tend to give themselves a relatively lower score for mathematical self-concept compared to students with similar performance surrounded by others who perform lower. This finding, known as the "Big Fish Little Pond effect," further emphasizes that being skilled in a particular subject does not equate to having the necessary self-efficacy to choose that subject in a study profile or further education.

The school context, including the quality and organization of education, appears to influence young people's interest in STEM but has been less studied. Young people who are enthusiastic about technology often experience a practical and future-oriented approach to technology in school, which further stimulates their interest. Conversely, young people who find technology less interesting often cite a lack of practical application and inspiring teaching methods as reasons for their reduced interest. Teacher feedback and the way they present and support technology appear to be factors influencing the choice of a technical education.

Integrated STEM education, which, for example, incorporates practical projects and interactions with experts into the existing curriculum, can increase interest in a technical educational and career profile. Five studies investigated the effectiveness of integrated STEM education. In four of the five studies, the effect of the integrated STEM education program was quantitatively evaluated. Only one program showed a statistically significant effect. This concerned the most extensive program, which spanned a total of 2.5 years and consisted of multiple components.
This finding underscores that each program must be evaluated on its own merits. One integrated STEM education program is different from another. Concluding that "integrated STEM education has a positive effect on young people's interest in STEM" would therefore be too simplistic. However, lessons can be learned from how effective programs have been developed and implemented.

The provision of extracurricular STEM activities seems to have no influence on the choice of a STEM subject in the English "upper secondary" according to a large-scale international study. However, there are several methodological concerns with this study, particularly regarding the classification of the active group (the group exposed to extracurricular STEM activities) and the control group. Nevertheless, this study is interesting due to the different approach taken compared to other studies that evaluate extracurricular STEM activities. In this large-scale study, all students to whom the school offered an extracurricular STEM activity were included, regardless of whether they participated or not (intention-to-treat analysis). Moreover, the study used a longitudinal design with multiple follow-up measurements, allowing for more certainty in drawing causal conclusions. When the goal is to engage a broader group, merely demonstrating a positive relationship between participation and interest is not enough. A positive relationship between children who choose to participate in an extracurricular STEM activity and interest in a STEM career may arise due to selection bias. When selection bias is present, mainly children who are already interested in STEM choose to participate in the extracurricular activity. Interest may be reinforced for this already interested group. However, when the goal is to engage a broader group, it is more accurate to look at all students who had the opportunity to participate, regardless of whether they took advantage of that opportunity. Having a good control group is essential. Furthermore, no high-quality research has been found showing that offering extracurricular STEM activities also reaches and positively influences the "non-interested" target group.

One study was conducted in the Dutch context. Schools visited companies and received explanations. The program group scored significantly higher on perceived enjoyment before the company visits compared to after the visits. However, no significant difference was measured between the control and program groups. The effectiveness of the program could therefore not be demonstrated. Observations by the researchers revealed, among other things, that "The tasks at the technical companies were mostly 'hands-on' and stereotypical (e.g., working with machines)."

An interim evaluation with the possibility of adjusting the program and discontinuing it if necessary seems crucial in the further development of Technology Promotion. For example, an online mentoring program in which participants in Germany participated for at least one year had no significant effect on participants' certainty in choosing a STEM career in the future. The program was offered for nine years, with a total of 4,017 participants included. Although it is sometimes useful to follow the effects of a program over a longer period, the question is whether the conclusion of this study could have been drawn earlier.

Educational reforms in Germany (2002) and Latvia (2014-2020) related to STEM education had limited influence on educational choices. The German reform involved restricting students' freedom of choice in secondary education between basic or advanced subjects. After the reform, all students were required to take five subjects from specific fields (e.g., German, mathematics, foreign languages, sciences) for four hours per week. Research on this reform showed no significant change in enrollment in technical education. The Latvian reform focused, among other things, on new state standards developed for all levels of education, a mandatory centralized mathematics exam for secondary school graduates, and the redistribution of state budget funding in favor of STEM fields. Finally, a project "Sciences and Mathematics" (funded by the European Structural Funds) was implemented in both primary and secondary schools. This reform also did not result in increased interest in STEM.

Background

Internationally, there is an increasing amount of scientific research being conducted to gain more insight into what influences children and young people's choice for STEM and which programs are effective in steering this choice (Sáinz et al., 2022). The current literature review aims to summarize the international and national scientific literature on the factors influencing the choice of a technical education. Understanding the personal, environmental, and socio-demographic variables—referred to as determinants—that are associated with the choice of a technical profile makes it possible to formulate concrete leverage points and objectives for future interventions (Bartholomew Eldredge et al., 2016). In addition to researching the determinants of the choice for a technical education, intervention studies were also examined. On the one hand, to see which determinants programs (interventions) that have been studied for their effect target, and to what extent those determinants indeed drive choice behavior. On the other hand, to see which types of programs can be distinguished and to what extent they can be effective.

International regions and within them, countries differ in how primary and secondary education is organized. Additionally, there are other factors that can vary greatly between regions and countries, such as the economic development of a country and thereby the need for ICT and technically skilled personnel. The current research aims to identify determinants that are important for the Dutch context. However, because relatively little systematic research has been conducted in the Netherlands on the determinants of the choice for a technical profile, which goes beyond descriptive research into the role of socio-demographic variables such as gender, parents' education, and school performance, it was decided to expand the literature review with studies conducted in Western Europe and North America. The nature of society and the way education is organized are considered comparable, so results may also be relevant for the Netherlands.

Theoretical Framework

To influence the choice for a technical profile in the desired direction, insight into the personal, environmental, and socio-demographic factors that drive this choice behavior is essential. Only a good understanding of the factors that drive, enable, or reinforce behavior can lead to the development of effective behavioral interventions. Socio-demographic factors such as gender, education level, and socioeconomic status are personal characteristics that can help select target groups and further subdivide them into subgroups. Generally, these factors are not or are very difficult to change. Environmental factors are variables over which members of the target group have no control and that can either promote or hinder the performance of behavior. Examples of environmental factors include the accessibility of appropriate education, cultural and social norms. The responsibility and possibility for making adjustments to environmental factors generally lie with policymakers and other external decision-makers. Finally, personal factors are those that lie within the individual, over which the individual has control, and that can be influenced through information and education. These include variables such as factual knowledge, considerations regarding the benefits and costs of certain choices, the self-efficacy one experiences, and the skills one possesses, so-called social cognitive or psychosocial determinants of behavior.

Social cognitive theories of behavior describe the key psychosocial variables that explain behavior. Important theories include Albert Bandura's social cognitive theory, Martin Fishbein and Icek Ajzen's theory of planned behavior or reasoned action approach, and Ronald Rogers' protection motivation theory. These theories show a great deal of overlap in describing the key determinants that explain behavior; largely, they are the same psychosocial concepts with different labels. What these theories have in common is that they see motivation as the main predictor of behavior, provided the person has the skills to perform the behavior and there are no factors in the immediate environment that hinder or even make it impossible to perform the behavior, such as high tuition fees or insufficient housing in the place of study. Motivation, skill, and the absence of hindering factors are three necessary conditions for performing behavior. Skills can be trained. Hindering factors can be removed by external parties. According to the various theories, a person's motivation or intention to perform behavior is strengthened when the person sees more benefits than disadvantages in performing the behavior (makes a positive cost-benefit analysis), expects to experience a positive feeling, expects that important others (family, friends, peers) will be more likely to approve than disapprove of the behavior or also perform the behavior, and has confidence in successfully performing the behavior and perceives sufficient control over its execution. These predictors of intention are referred to as instrumental and affective attitude, injunctive and descriptive subjective norm, and self-efficacy and perceived behavioral control, respectively.

In the articles included in the current literature review, social cognitive theory is particularly prominent in the form of social cognitive career theory (Lent et al., 2010). In line with social cognitive theory, this theory posits that a person's choice for technology is a function of the individual and their environment. It is suggested that people develop their interest in technology largely based on their belief in their own (academic) skills (self-efficacy) and the outcomes their efforts could yield (outcome expectations). Additionally, the environment must be structured in such a way that a choice for technology is not hindered by factors over which the individual has no direct control.

Method

Prior to the literature review, the main problem and the focus of the research were determined in consultation with the commissioners of the current research report. This approach is in line with the methodology described for Intervention Mapping. A thorough understanding of the problem contributes to a better understanding of the factors on which future programs should focus to subsequently formulate concrete program goals, select appropriate strategies, and determine how to implement them (Ruiter & Crutzen, 2020).

- Main Problem: Too few adults choose to work in the technical sector in the Netherlands (Techniekpact, 2022).
- Problem Focus of the Current Research: Interest in technical professions is formed during the last phase of primary education and the first phase of secondary education, in the age group of 9 to 15-year-olds in the Netherlands (Langen & Meelissen, 2019; Stoet & Geary, 2018).

In line with this delineation and the assignment of the current research, the following research questions were formulated:

1. What factors influence the choice of, or interest in, a STEM subject, study profile, further education, or career for children in primary education?
2. What factors influence the choice of, or interest in, a STEM subject, study profile, further education, or career for young people in the first phase of secondary education?
3. What programs (interventions) are effective in influencing the choice of, or interest in, a STEM subject, study profile, further education, or career for children in primary education?
4. What programs (interventions) are effective in influencing the choice of, or interest in, a STEM subject, study profile, further education, or career for young people in the first phase of secondary education?

Search Strategy

Two databases of scientific literature relevant to the research assignment, Pubmed and ERIC, were searched between July 2023 and October 2023. The specific search terms and search strings can be found in Appendix 1. Articles were screened by title by both researchers (HvP and RR). In case of disagreement, discussions were held until consensus was reached. One researcher (HvP) read the abstracts of the articles. When articles were included based on title and abstract, the full text was read if available (HvP). If there was doubt about including articles based on the full text, the second researcher (RR) was consulted. In addition to the articles found in the Pubmed and ERIC search, articles shared by the commissioners of the current assignment were screened.

Inclusion Criteria

The following inclusion criteria were applied to the selection of articles:

- The outcome measure concerned interest in, or choice of, a Science, Technology, Engineering, and Mathematics (STEM) subject, study profile, education, or career. STEM was chosen instead of only "technology" because the latter term is difficult to delineate in an international literature review.
- The target group consisted of children or young people aged 9 to 15 years, i.e., students in the upper grades of primary education or lower grades of secondary education (i.e., the phase before a choice must be made for a STEM profile).
- The search terms primarily delineated the geographical location, focusing on Northern and Western Europe, due to the comparability with the Dutch youth population and educational context. However, during the inclusion of articles based on title and abstract, it became clear that much research was excluded. Therefore, within the existing search strings, a broader

inclusion was adopted, which also included research from the United States and Canada in the literature review.
- Research concerned the general youth population and not a specific subpopulation, such as children or young people with a specific diagnosis (such as autism) or a specific cultural or socioeconomic background.
- Only research published in the last 10 years was included, due to the rapidly changing environmental factors, particularly in the area of digitalization and social media use, which can influence the decision-making behavior of children and young people.

Data Extraction

Information from articles included based on full-text analysis was recorded by one author (HvP) in a data extraction table designed for this research. Data extraction involved information related to the target group (e.g., age, location of the research), study design (e.g., cross-sectional vs. longitudinal), underlying model and/or theory supporting the study design (if applicable), the program (if applicable), the main outcome measure, sub-outcome measure, result/conclusion of the study, and an assessment of the study's quality.

Quality Assessment

Due to the large diversity of types of studies included in the current study, existing quality assessment forms were not used for the quality assessment. An intuitive approach was chosen, where quality was partly determined based on the research design, data collection method, statistical analysis, sample size, and scientific journal in which the article was published. One researcher (HvP) primarily made the assessment. If an article received the preliminary classification of 'low quality,' consensus was sought with the second researcher (RR). The categories 'low,' 'moderate,' 'sufficient,' and 'good' were used.

Analysis

The diversity and resulting heterogeneity in the nature and quality of included studies make it impossible to perform a statistical analysis (meta-analysis) on the included articles. The analysis and conclusion of the current research are therefore descriptive in nature. Research questions 1 and 2 focus on factors that influence the choice of, or interest in, a technical profile or career for children in primary education and young people in the first phase of secondary education. To answer this question, both explanatory and intervention research was studied. Included articles were examined for theoretical frameworks and models to identify possible additional behavioral determinants.

The conceptual framework for choices and transitions in STEM/technical education that Langen and Meelissen (2019) designed based on various meta-reviews was used as a guideline to organize the findings of the current research. These include student-related factors such as aptitude, attitude, performance, motivation, or family characteristics; school-related factors such as didactics, offered curriculum, policy, school climate; and environmental factors including national policy and prevailing social and cultural values and norms. The outcome measure 'interest in/choice of a STEM career' was added to the model by Langen and Meelissen (2019) (see Figure 8).

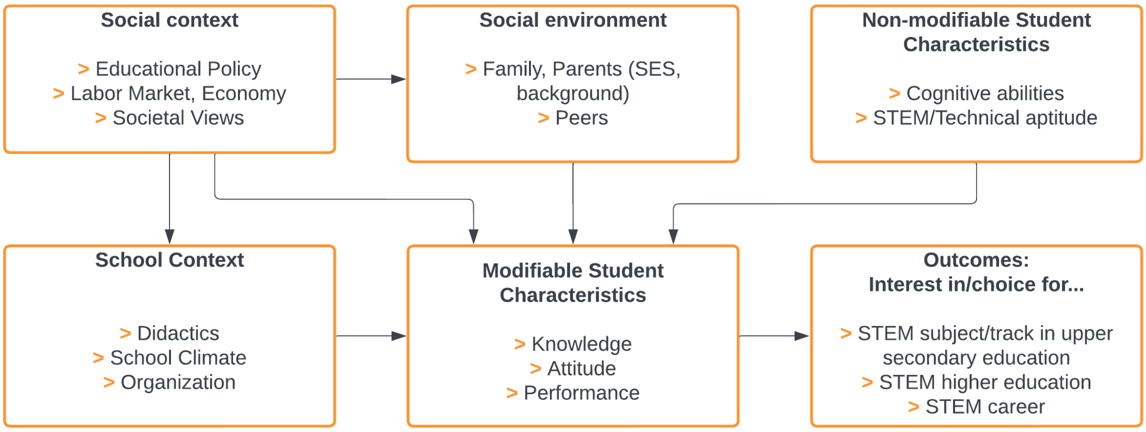

Figure 8. Model for Interest in and Choice of STEM Education and Work

Results

Study Selection

In total, the searches on Pubmed and ERIC yielded 322 articles, of which 268 were unique. After screening titles, abstracts, and full texts, 26 articles remained. Out of the 24 articles provided by the commissioners of the current assignment, two articles were included (Ait Moha, Muller & Thijssen, 2019; Post & Walma van der Molen, 2014). Additionally, one article from the *Platform Talent voor Technologie* website was selected for the current literature review (Platform Talent voor Technologie, 2023). Finally, three more articles were included based on the reference lists of the included articles (Archer et al., 2013, Mujtaba & Reiss, 2014, Stoet & Geary, 2018).

Study Characteristics

The geographical locations where research was conducted involved populations in the United States (n=7), Canada (n=2), Germany (n=4), England (n=8), Finland (n=2), Latvia (n=1), the Netherlands (n=3), Norway (n=1), and Slovakia (n=1). In the study by Kang et al. (2023), students from Germany, Estonia, and Finland were included, and results were presented as one sample. Both Stoet & Geary (2018) and Niepel, Stadler & Greiff (2019) used the international PISA database and included 67 and 23 countries in their analyses, respectively.

In 26 studies, the influence of behavioral factors or the effect of programs on interest in STEM among secondary school students was investigated. Three studies included both primary school children and young people in lower secondary education (Ait Moha, Muller & Thijssen, 2019, Kompella et al., 2020, Alexander et al., 2022). Only two studies exclusively included primary school children (Dunlop et al., 2019, Post & Walma van der Molen (2014)). Henriksen, Jensen & Sjaastad (2015) conducted retrospective research in which students who had already chosen a STEM education were asked which interventions in the past had influenced their educational choices. Specific interventions during primary or secondary education were not explicitly requested. Due to the low number of studies involving primary school children, no distinction was made between the target groups in the description of the results.

In 11 of the 32 studies, the effect of a program was investigated. Nineteen studies focused on exploring the influence of one or more determinants on the decision-making behavior of children and young people. Both Rozek et al. (2017) and Kovarik et al. (2013) examined the influence of one or more determinants on decision-making behavior in addition to the effect of a program.

Quality Assessment

Only a few articles were rated as "Good" (n=3; Beckman (2021), Blotnicky et al. (2018), Franz-Odendaal (2016)). These articles all included a statistical analysis based on regression models, where the choice of determinants included in the models was based on theoretical frameworks from the behavioral sciences, and the sample sizes were considered sufficient (respectively n=8711, n=1448, and n=531). None of the studies investigating the effect of a program were rated as "good." Eight articles were rated as sufficient. The reason for a lower quality score of these articles compared to those rated as "good" varies per article. For example, a lower classification may be due to the inclusion of a limited number of determinants, potentially overlooking confounding determinants (Starr, Ramos Carranza & Simpkins, 2022). The majority, however, fell into the categories of moderate (n=12) and low (n=9). Articles of moderate quality more frequently included self-developed measurement instruments that were not assessed for validity, had basic statistical analyses, and/or lacked a control group in evaluating the effect of a program. For the articles classified as "low quality," only descriptive research was conducted, and in some cases, the methodology behind the results was not described (Platform Talent voor Technologie, 2023, Ait Moha, Muller & Thijssen, 2019), or the sample size in research on determinants was very limited (Siani & Dacin (2018), Siani & Harris (2023), with n=60 and n=82, respectively).

Outcome

In several articles, the term "science" is used to refer to a component of the curriculum for young people. "Science" usually refers to chemistry, physics, or a combination of chemistry, physics, and biology. In the United States, it is common for high school students in their first year of high school, when they are 14 to 15 years old, to first take biology. The following year, they take chemistry, and only in the third year of high school do they take physics (Mays, 2016). Although this is the usual sequence, it is not always followed; for example, students may be offered physics first (Mason, 2002). In most studies, it is not specified which topics "science" includes and which subjects the students included in the research had already taken. In all cases where this is not specified, the term "science" is used.

Modifiable Student Characteristics

Self-efficacy

The influence of self-efficacy—i.e., confidence in one's own abilities—was investigated for all outcome measures: the choice of a STEM subject in upper secondary education, a STEM further education, and a STEM career. For all outcomes, a correlation was found between self-efficacy concerning STEM skills and interest in or choice of STEM.

In the study by Kaleva et al. (2019), students were asked after their choice of advanced or basic mathematics in upper secondary education what influenced their decision to choose or not choose advanced mathematics. The fear of not passing an advanced subject, an indication of low self-efficacy, was one of the most frequently mentioned reasons for choosing basic mathematics instead of advanced mathematics. The Platform Talent voor Technologie (2023) article also concluded that only a small proportion (9%) of students who consider themselves poor in STEM subjects choose a technical profile.

In addition to the descriptive studies by Kaleva et al. (2019) and Platform Talent voor Technologie (2023), the influence of self-efficacy regarding physics on the choice of a STEM subject was also statistically demonstrated by Mujtaba & Reiss (2014). Mujtaba & Reiss (2014) found a significant effect of the construct "physics self-concept" on the intention to include physics in the self-chosen subject package. In a separate analysis, the unique items that comprised the "physics self-concept" construct were included. It was found that the positive relationship between self-efficacy and intention was primarily driven by two items: "I am good at physics" and "I don't need help with physics."

Perez-Felkner et al. (2012) conducted a longitudinal cohort study. It examined the effect of various determinants on the choice of further education in physics, engineering, mathematics, and computer science (PEMC) compared to the fields of biological sciences, social and behavioral sciences, or clinical and health sciences. When students in the 10th grade, which in the American school system means that young people are 15 to 16 years old, gave themselves a higher score on the construct "experienced math skills," consisting of the items "I can understand a difficult math lesson" and "I can master math skills," they were more likely to choose further education in PEMC compared to young people who had a low score on this construct. In an additional analysis that examined the effect of different determinants separately for students who chose a standard math package versus an advanced math package in high school, the relationship between experienced math skills and the choice of a PEMC further education was confirmed for both groups. In other words, even for young people who are skilled enough to choose an advanced math subject, the level of self-efficacy they have in the subject remains important in the choice for PEMC. Students who scored higher on the statement "I believe that most people can learn to be good at math" were also somewhat more likely to choose a PEMC further education.

Blotnicky et al. (2018) found that young people with a high score for "math self-efficacy" indicated a greater interest in a future career in science, technology, healthcare, or engineering. Siani & Harris (2023) found a strong positive correlation between female students' interest in a future career in science and their self-efficacy in math. This relationship was also found for interest in a math-related career and self-efficacy in science. However, female students' interest in a future career in technology/engineering was not significantly correlated with their self-efficacy in math or science. In the study by Niepel, Stadler & Greiff (2019), PISA data from 23 countries were combined. In analyses where data from male and female students were modeled separately, it was found that the "math self-concept" among female students was higher in societies where female participation in technical professions was relatively higher.

Kovarik et al. (2013) measured interest in STEM using the construct "engagement" at two time points, before the start of the bioinformatics curriculum and after its completion. This construct consisted of both an item regarding interest in a profession involving scientific information and items regarding interest in more specific STEM subjects, such as interest in using computer programs to visualize 3D images of molecules. The questions that the researchers identified as questions related to self-efficacy were strongly focused on the specific subject that the curriculum covered, not on STEM in the broader context. For example, "I understand how databases store biological information for research" and "I feel comfortable finding biological information in databases." The longitudinal design of the study allowed for multiple analyses to examine the relationship between the construct "engagement" and "self-efficacy." A positive relationship was found between engagement and self-efficacy both before and after the start of the bioinformatics curriculum. Additionally, an increase in engagement over time was accompanied by an increase in self-efficacy.

Alexander et al. (2022) examined the influence of two constructs related to self-efficacy. The construct "Hopeful Future Expectations" consisted of the statements "My education will create many future opportunities for me" and "School will help me achieve my future goals." This construct was a significant and positive predictor of interest in a STEM career. The score on the construct "Purposeful Self-Regulation," consisting of the statements "At school, when things don't work the way they normally do, I look for other ways to achieve them" and "At school, when I set a goal, I stick to it," was not a significant predictor of interest in a STEM career in the main analysis. In a sub-analysis, a significant relationship was found between purposeful self-regulation for girls in lower secondary education, but not for boys in lower secondary education or girls and boys in upper secondary education.

STEM Skills

Skill levels can be determined by asking young people how skilled they consider themselves—referred to above as self-efficacy—or through an objective measurement. In the articles below, skill level was determined based on objective test scores.

Codiroli Mcmaster (2017) conducted research on English students. It is important to know that English students are required to attend school until the age of sixteen. This period ends with an exam (General Certificate of Secondary Education, GCSE). After this, the student can choose to obtain an "A-level" in two years for three to four subjects, which are usually relevant to the intended further education (Bright World, n.d.). In the study by Codiroli Mcmaster (2017), the choice to take at least one 'A-level' STEM subject was predicted. Among other things, the relationship between this choice and GCSE score and scores for various subjects at the end of 'Key Stage 2' (KS2, age seven to 11 years (Bright World, n.d.)) was investigated. The earlier performances of students were positively associated with the choice to take at least one A-level STEM subject. Overall, students' prior knowledge was positively associated with choice, except for knowledge of KS2 English. Children with a high score in KS2 English were less likely to choose an A-level STEM subject than children with a low score in KS2 English.

Rozek et al. (2017) found that the ACT score (i.e., American College Testing, a standardized American test used for higher education admission) in math and science was a significant predictor of taking STEM courses in college. Students with higher ACT scores in math and science were more likely to enroll in STEM courses in college.

Perez-Felkner et al. (2012) found a positive relationship between the math skill score in the 10th grade and the choice of a PEMC further education. A separate analysis showed that the influence of math skill in the 10th grade on the choice of a PEMC further education was stronger for students who chose a standard math package in high school compared to students who chose an advanced math package in high school.

In the study by Stoet & Geary (2018), PISA data from girls in 67 countries were included to explain girls' choice to pursue a STEM further education. Stoet & Geary classified students as "potentially successful in STEM" when they scored level four (on a scale of up to six) in science, math, and reading. Based on this skills-focused classification, it was calculated that many more women would be suitable for STEM than the percentage of women who actually chose a STEM education. The researchers concluded that STEM skill alone is not the only factor determining the choice of STEM further education.

Relative Strength in STEM

The anecdotes included in the report from Platform Talent voor Technologie (2023) provide a good insight into the reasoning behind not choosing a STEM profile based on relative strength, and thus relative costs, from the student's perspective:

"*STEM was much harder than I expected. I also just want to keep doing fun things. I switched to E&M. I have to work a lot less now and have more time for other things. I just want to graduate without failing*."
"*For other subjects, I can just read the night before and get an eight. That is not possible with STEM subjects. I really have to keep up with the assignments*."

The study by Stoet & Geary (2018) revealed that, on average, 28% of women internationally chose a STEM further education. The researchers calculated "STEM potential," or the female students who could potentially choose a STEM education, in three ways. The first calculation only considered skills, requiring a score of at least four out of six on the PISA scale in science, math, and reading. If all female students who met this criterion had chosen a STEM further education, 49% would have been observed. This was much lower, as mentioned, with 28%, leading the researchers to conclude that skill could not be the only determinant that influences female students' choice of STEM further education. The researchers then added the condition to the calculation to score at least the international average in enjoyment, interest, and self-efficacy in science. The percentage of female students who were both skilled and interested, and who also scored on average for enjoyment and self-efficacy, was 41%. Finally, the researchers added the condition that either science or math was the student's relative strength. A student's relative strength is the subject in which they score the highest, relative to their own scores in the other two subjects. This significantly reduced the calculated STEM potential to 34%, and the gap between STEM potential and the observed international average of 28% was smaller.
Even if girls perform better than boys in science, as was the case in Finland, girls generally perform better in reading, which means their individual strength, unlike that of boys, is reading. Gender differences in relative strength were almost universal: on average (in all countries), science was the strength of 24% of girls, math was the strength of 25% of girls, and reading was the strength of 51% of girls. The corresponding values for boys were 38% for science, 42% for math, and 20% for reading. This pattern may explain why many more boys than girls pursue a STEM education.

The fact that being skilled in STEM subjects alone is not a predictor of choosing STEM is also highlighted in the study by Perez-Felkner et al. (2012). A higher math score in the 10th grade increased the likelihood of choosing further education in physics, engineering, mathematics, and computer science (PEMC), but also the likelihood of choosing further education in social and behavioral sciences. Additionally, a higher math score significantly decreased the likelihood of choosing a PEMC further education for women, while it increased the likelihood of choosing further education in social and behavioral sciences.

Familiarity with STEM Careers

Ait Moha, Muller, and Thijssen (2019) created a segmentation model based on a combination of qualitative and quantitative research, clustering young people into distinct groups. Based on these analyses, they categorized young people into one of five segments: Innovators, Social Appliers, Doers, Explorers, and Creative Makers (see Figure 9). Each segment shows as much similarity as possible between young people within the segment, and a segment differs as much as possible from the other segments. The segments differ from each other based on seven factors (see Figure 10). Significant and typical differences between the segments were described. All respondents were asked what possibilities they saw to make technology more attractive. The "Creative Makers" segment did not provide explicit advice. What is striking is that despite the many differences between the segments, tips related to familiarity with STEM careers

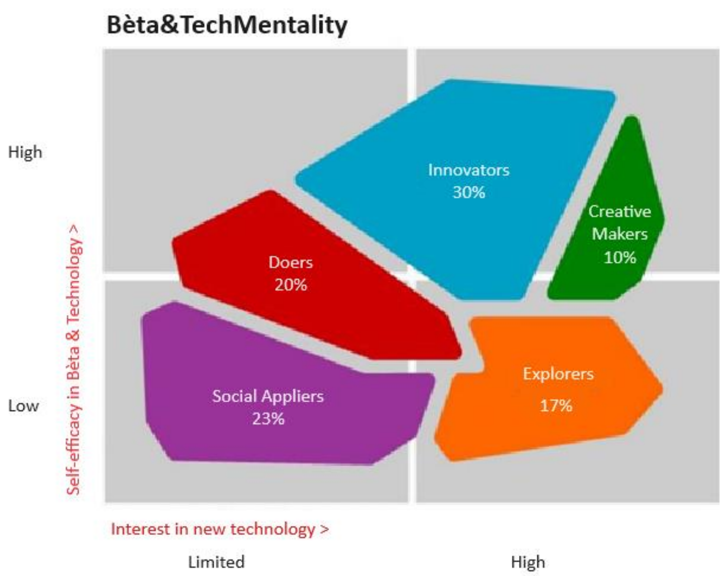

Figure 9. Bèta&Techmentality Segments

were mentioned by all other segments: "Make it clearer what you can do with it later," "Make technology more practice-oriented," and "Focus on people and society."

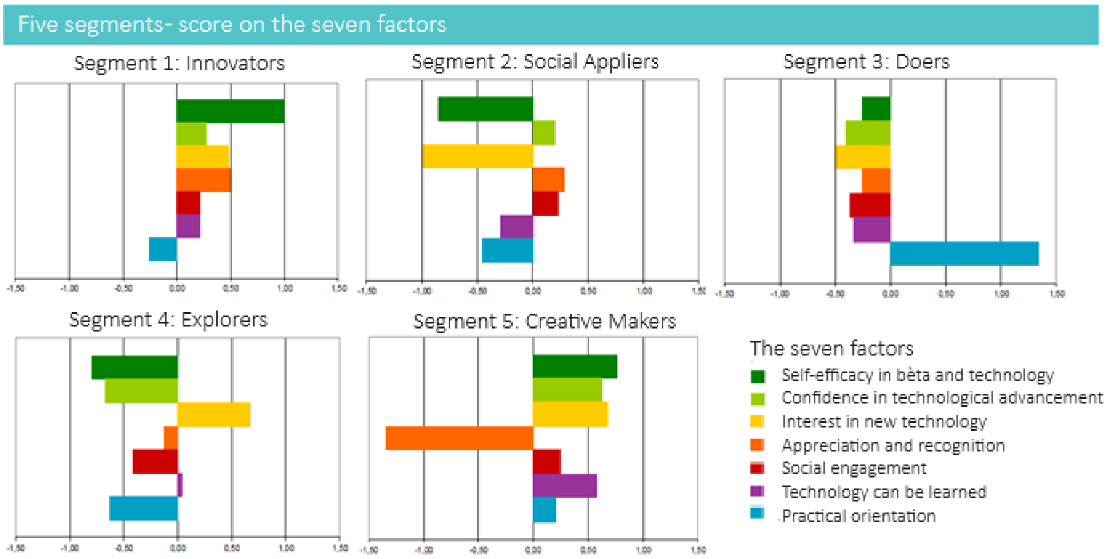

Figure 10. Influence of Seven Factors on Beta&TechMentality Segments

In the survey by Platform Talent voor Technologie (2023), students who had not yet decided on their profile choice more often indicated that the choice for STEM would be greater if it were clearer what the subjects contribute to society. Havo students who did not choose a technical profile indicated that they might have done so if it were clearer what they could do with it later. This was not indicated by students from vmbo-b/k/g, vmbo-tl, or Vwo who did not choose a technical profile.[2] Students who did choose a STEM profile, compared to students who did not choose this profile, more often indicated that during LOB (career orientation and guidance), they had a good idea of what they could do with STEM subjects (59% vs. 46%) and what STEM subjects contribute to society (61% vs. 41%).

Another notable finding from the survey by Platform Talent voor Technologie (2023) is that technical professions are seen by many students as less often important to society. Franz-Odendaal et al. (2016) found that when students were asked what they thought engineers did, the most common answer was "build things" (68% of respondents), and the least common response was that engineers "make the world a better place" (4% of respondents). About 18% of participants indicated that they did not know what engineers did.

In the study by Blotnicky et al. (2018), students were asked to indicate for different STEM careers whether it was necessary to take math or science in high school to calculate a "scientific career knowledge-score." The regression analysis showed that students with stronger scientific career knowledge-scores were slightly more likely to pursue a STEM career than students with weaker scientific career knowledge-scores. Students were also asked to rank six career activities based on preference. These were (1) artistic, unusual, and creative activities; (2) working on practical, productive, and concrete activities; (3) taking responsibility, providing leadership, and persuading others; (4) organizing things into routines and maintaining an overview; (5) learning through reading, studying, analyzing, or research; (6) helping others and caring for others' well-being. Students who

[2] In the Netherlands, there are different types of secondary education: pre-vocational secondary education (VMBO), senior general secondary education (HAVO) and pre-university education (VWO) (Ministry of Education, Culture and Science, n.d.). VMBO has four learning paths: basic vocational training (vmbo-b), vocational training (vmbo-k), mixed: between vmbo-k and vmbo-tl (vmbo-g) and theoretical (vmbo-tl) (Rijksoverheid, n.d.). After completing VMBO, pupils go to secondary vocational education (MBO) or to year 4 of HAVO (Ministry of Education, Culture and Science, n.d.). This last option is available for pupils who completed four years of vmbo-tl.

ranked activities related to reading, studying, analyzing, and research in their top two were 1.8 times more likely to be interested in a STEM career than students who did not rank this activity in their top two. For students who preferred activities related to routine and maintaining an overview, the odds were 1.51 times higher, and for students with a preference for practical, productive, and concrete activities, the odds were 1.48 times higher. The remaining career activities were not statistically significant predictors of the likelihood of pursuing a STEM career. Blotnicky et al. (2018) concluded based on these findings that "Students are interested in careers that involve a wide variety of activities but do not appear to relate these activities to STEM careers."

Kang et al. (2023) concluded that being informed about which science-related careers exist, where students can find information about them, and what steps they need to take if they want a career in this sector is more important than being prepared. "Being prepared" means that the courses students could take gave them sufficient knowledge and skills for a science-related career. The preparation construct was not significantly correlated with ambitions, while the information construct not only showed a positive relationship but also had an amplifying effect on ambitions for a career in science.

Instrumental Attitude

Kaleva et al. (2019) found that the most reported reason for choosing advanced mathematics was its usefulness. Many students indicated that they thought advanced mathematics opened more options for their future careers or study places. Students in the study by Perez-Felkner et al. (2012) who scored higher on the question "math is important" were more likely to choose further education in physics, engineering, mathematics, and computer science.

In the survey by Platform Talent voor Technologie (2023), students who chose a STEM profile, compared to students who did not, more often indicated that they believed that a STEM education gives you a good chance of getting a good job (75% vs. 58%) and that you can go in any direction later if you choose a STEM direction (72% vs. 50%).

These findings are further confirmed by Mujtaba & Reiss (2014), who investigated the influence of seven physics-specific constructs on the intention to include physics in the self-chosen subject package. The construct "Extrinsic material-gain motivation" concerned the extent to which a student was convinced that choosing physics in the self-chosen subject package could lead to a quantifiable reward, such as access to higher education or future career opportunities. This construct was found to have the most influence on the outcome measure of the seven constructs investigated. In a sub-analysis of the individual items within the construct, a significant effect was found for the item "Physics will help me in the career I want to pursue in the future."

In the study by Franz-Odendaal et al. (2016), students were asked to indicate through an open question which factors influenced their interest in a STEM career. Only 2% of the students mentioned money as an influencing factor. Binary logistic regression showed that this factor had no significant influence on interest in a STEM career.

Affective Attitude

Mujtaba & Reiss (2014) found an effect of the constructs "Perception of physics lessons" and "Emotional response to physics lessons" on the intention to include physics in the self-chosen subject package. In a sub-analysis of the individual items, significant effects were found for the item "I enjoy my physics lessons" from the construct Emotional response to physics lessons and the item "Physics is an interesting subject" from the construct Intrinsic value.

Analyses by Kang et al. (2023) showed that the construct "interest," consisting of items focused on, among other things, enjoyment, and relevance, positively predicts the level of STEM ambition. The

STEM ambition construct included both interest in a STEM education and work. Interestingly, although interest was already positively related to STEM ambition in the first, basic analysis, this effect became stronger with a higher level of preparation experienced by the student and information about a science-related career.

The results of Vinni-Laakso et al. (2019) among primary school students showed that the intrinsic value of science as experienced by students in the first grade had limited predictive value for STEM career ambitions in the second grade.

Non-Modifiable Student Characteristics

Gender

The gender of a student is, of course, not modifiable through education. However, research shows that there are gender-specific factors that can be influenced by programs, which would argue for gender-specific (tailored) programs.

Perez-Felkner et al. (2012) examined the potential moderating effect of gender differences on the relationship between choosing further education in physics, engineering, mathematics, and computer science (PEMC) and the construct subjective orientations. This construct consisted of questions about the level of engagement in math, how valuable a student finds math, whether the student can follow a difficult math lesson, the belief that most people can learn to be good at math, and participation in math class. This analysis suggests that although men and women statistically differ in subjective orientations, the differences are very small. Women who chose a PEMC further education seem similar to men in subjective orientations.

Girls and boys may have different needs concerning their future careers. For example, the survey by Platform Talent voor Technologie (2023) revealed that girls, compared to boys, more often find it important to do something for the environment (57% vs. 50%) and more often want a job that contributes to society (58% vs. 47%).

Ethnic Background

The influence of ethnic or cultural background is complex to understand, where the moderating influence of background is related to many other influences. A telling example of this complexity is the analyses by Perez-Felkner et al. (2012). For example, in the main analysis, it is found that the influence of having a "Latino" background on the choice of PEMC further education compared to the reference category "white" is negative when looking at the sample as a whole. On the other hand, a positive moderating effect on the enrollment of Latina women in PEMC is found compared to "white" women. Additionally, a sub-analysis shows that the influence of having a "Latino" background on the choice of PEMC further education differs greatly for students who chose a standard math package in high school compared to students who chose an advanced math package in high school. Students who chose a standard math package in high school and indicated that they were Latino had a higher likelihood of choosing PEMC further education compared to students in the reference category "white." For students who took an advanced math package in high school, however, the opposite was true; having a Latino background was a negative predictor for them in choosing PEMC further education.

This example shows that research on the influence of ethnic or cultural background should be conducted with caution. Instead, it is better to look at other factors that may be related to ethnic or cultural background and that can serve as an entry point for interventions, such as the influence of parents' opinions on educational choice, financial opportunities to participate in STEM activities, the quality of education followed in specific neighborhoods, beliefs about gender roles, etc. It is important to remain aware that the influence and the extent to which children conform to this influence can differ between, as well as within, different demographic groups.

Social Environment

When young people are asked an open-ended question about what determines their choice of education, "parents" or "peers" are not often mentioned by the youth themselves (Franz-Odendaal et al., 2016).

The segment “innovators” is described by Ait Moha, Muller & Thijssen (2019) as “the low-hanging fruit when it comes to motivating them for technical education.” Characteristic of the young people in this segment is that they indicate that their parents/caregivers played a key role in shaping their view of technology and their eventual choice of a school profile. They want a career that their parents/caregivers can be proud of, which is important in the context of their extrinsic motivation. For none of the other segments is it mentioned that parents have an influence on the young people's view of technology. For the segment “creative makers,” it is noted that the young people “do not experience external pressure from parents/caregivers in making choices about technology but are encouraged to choose a career they enjoy later on.” The young people in this segment are described as “Aware of their technical interest and talent, but not yet entirely sure how they want to shape that in the future.”

Parental Attitude Towards STEM

The survey by Platform Talent voor Technologie (2023) revealed that when parents/caregivers advise against it, the likelihood of students choosing a technical field is low (6%). On the other hand, if parents/caregivers recommend it, the likelihood is high (73%). If there is no advice or neutral advice, the likelihood of students not choosing a technical field is greater than the likelihood of them choosing one (63% vs. 37%). The document states that “There is a strong, statistically significant relationship between how good students perceive themselves to be in STEM subjects and the advice they receive from their parents to choose a STEM subject package.” However, the method of testing and the statistical result are not made clear in the document.

In the study by Mujtaba & Reiss (2014), a significant, positive relationship was found between the construct “Support from home for achievement in physics” and the intention to include physics in the self-chosen subject package. Harackiewicz et al. (2012) conducted a randomized study in which they informed mothers about the positive aspects of choosing STEM subjects in high school. They did this by providing brochures and a website, aiming to improve mothers' perceptions of STEM and increase communication about this topic between mothers and adolescents. Students in the program group were significantly more likely to choose mathematics and science in the last two years of high school than students in the control group. In a process analysis, the researchers delved deeper into the mechanisms behind the program's effectiveness. It was found that the program had a significant, positive effect on the “perceived utility value” (i.e., the perception of whether mathematics and science are relevant to the child’s future) of mothers in the program group regarding science and mathematics for their child. Additionally, students experienced a higher STEM utility value if their mothers reported a higher perceived utility and if they had more conversations with their parents.

As a follow-up study to the research by Harackiewicz et al. (2012), Rozek et al. (2017) examined five years after the program what its effect was on taking STEM subjects in college, STEM career ambition, and STEM college major. No significant direct effect of the intervention was found for any of these outcomes. However, an indirect effect of the program on college STEM subject choice and STEM career ambition was found, through the program's effect on high school STEM preparation outcomes. This indirect effect was not significant for STEM college major.

In the study by Starr, Ramos Carranza & Simpkins (2022), analyses were conducted separately for students with university-educated parents and non-university-educated parents. The study examined the influence of various factors on the maintenance or loss of interest in STEM during the transition from 9th grade to 11th grade among young people. Starr, Ramos Carranza & Simpkins (2022) found that among students with non-university-educated parents who started 9th grade with STEM career expectations, those who received STEM support from their parents were more likely to maintain their STEM career expectations in 11th grade. Additionally, students with non-university-educated parents who started 9th grade with non-STEM career expectations and received STEM support from their parents were more likely to switch to STEM career expectations in 11th grade. STEM support from parents was not significantly related to whether students with university-educated parents maintained their STEM career expectations. However, STEM support from university-educated parents had a positive, significant effect on the likelihood of students who started 9th grade with non-STEM career expectations switching to STEM career expectations in 11th grade, compared to maintaining non-STEM career expectations.

Parental Education Level

The influence of parental education level on the choice of a STEM subject in upper secondary school was studied by Harackiewicz et al. (2012). This analysis found that students with parents with a higher education level were more likely to choose mathematics and science in the last two years of high school. Siani & Dacin (2018) found that 50% of students with at least one parent holding a university degree aspired to a STEM career, compared to 25% of students whose parents did not have a university degree.

Starr, Ramos Carranza & Simpkins (2022) found that among students who aspired to a STEM career in 9th grade, those without university-educated parents were significantly more likely to lose their interest in a STEM career during the transition to 11th grade compared to students with university-educated parents. Among students who did not have STEM career expectations in 9th grade, those with non-university-educated parents were significantly more likely than students with university-educated parents to maintain their non-STEM expectations from 9th to 11th grade (instead of switching from non-STEM to STEM career expectations).

Codiroli Mcmaster (2017) found a different result regarding the influence of the father's education level compared to the mother's: students whose mother had a degree were less likely to study STEM A-level, while students whose father had a degree were more likely to study STEM A-level.

Parental Occupation

Platform Talent voor Technologie (2023) found that students whose parents work in a technical field are slightly more likely to choose a STEM profile. Of the children with one or both parents working in a technical field, 47% chose a STEM profile, compared to 42% of children with parents who did not work in a technical field. Additionally, students who were exclusively interested in a STEM profile were more likely to have one or both parents working in a STEM-related job (45%, compared to 37% on average).

In the study by Ait Moha, Muller & Thijssen (2019), it was found that young people in the “innovators” segment had the most interest in a career in technology. They also more often indicated that one of their parents/caregivers worked in a technical or exact science job. This was not mentioned for the other segments.

Socioeconomic Status

Mujtaba & Reiss (2014) found no relationship between the “free school meals” status, often used as an indicator of socioeconomic status, and students’ intention to include physics in their self-chosen subject package. Similarly, Codiroli Mcmaster (2017) found no relationship between parental income, social class, or whether students attended an independent school and students' participation in STEM A-level subjects. Banerjee (2017) found no difference in the influence of the availability of STEM activities on the choice of A-level STEM subjects for students with “free school meals” status compared to students who did not have this status.

Peer Influence

Beckmann's (2021) analysis showed that an increase of one scale point in the mathematical confidence of classmates was associated with a 6.5 percentage point increase in the likelihood that men expect to pursue a STEM career, while a similar shift for women led to a 5.9 percentage point decrease. The researcher concluded that the social contrast effect was confirmed for women, and the social assimilation effect was confirmed for male students. This means that women have lower STEM expectations in classrooms with a high average score for mathematical confidence, while men have higher STEM expectations when they are part of groups with strong mathematical confidence.

Niepel, Stadler & Greiff (2019) investigated the “Big Fish Little Pond Effect” (BFLPE): students from schools that perform highly in a particular subject often score lower on an academic self-concept scale than students with the same skill level at a lower-performing school (Marsh, 1987). In line with the predictions of the BFLPE, a higher school average in mathematics was found to be negatively related to the individual mathematical self-concept of students. Students at schools with higher average math performance thus exhibited a slightly lower mathematical self-concept.

School Context

Quality and Structure of Education

The young people and children in the “Innovators” segment of the segmentation model by Ait Moha, Muller & Thijssen (2019) have a great interest in technology and a fascination with technological developments. According to them, a lot of attention is paid to technology at school. They associate this with enjoyable education, where they can practically engage with experiments. Additionally, “Innovators” find technology in education future-oriented and therefore interesting and useful. In contrast to this segment is the segment “Social Appliers.” They are not interested in technology and seem to have lost interest in technical education at school. Characteristics they associate with technical education were it being less easy, boring, and not useful, uninteresting textbooks, few good teachers and explanations, and little opportunity for hands-on activities.

In the survey by Platform Talent voor Technologie (2023), students who did not choose a technical profile indicated that they might have done so if the teachers' explanations were better. Students who were still undecided about their choice more often answered that the likelihood of choosing STEM increases "If you can do more practical assignments or experiments in class." A vivid anecdote from this study shows the influence of lesson structure on the perception of a subject: "*Chemistry is the most boring subject in school. We just have to memorize from books and have only had three experiments so far. I thought we would do a lot more experiments*."

In the study by Kaleva et al. (2019), students were asked after choosing advanced or basic mathematics in upper secondary school what had influenced their choice. Teaching style or quality was only mentioned a few times spontaneously as a factor influencing this choice.

Teacher Feedback

Children and young people who fall into the “Creative Makers” segment of the segmentation model by Ait Moha, Muller & Thijssen (2019) have few external influencers. Only the primary school teacher is decisive in their view of technology. For the “Explorers” segment, there are many different external influencers identified as important sources for choosing a secondary school or profile, from vloggers to cousins and primary school teachers. For the “Innovators,” “Social Appliers,” and “Doers” segments, teachers are not mentioned as a possibility for influencing the perception of technology.

In the survey by Platform Talent voor Technologie (2023), students from Vmbo-b/k/g and Vwo who did not choose a technical profile indicated that they might have done so if teachers were more positive about what students can do, for example, by giving more compliments. Students who were still undecided about their choice also more often indicated that this would increase the likelihood of choosing STEM. Students who chose a technical profile, compared to students who did not, were much more likely to indicate that they were motivated to pursue a technical career during career orientation and guidance (38% vs. 19%) and were encouraged to consider further studies in STEM (52% vs. 30%).

Skipper & Leman (2017) investigated the influence of teacher feedback in an experiment. In the experiment, students were asked to vividly imagine a scenario. In the scenario, all students were told they would be the first to choose a new engineering subject. The teacher of the new subject would base their opinion on the students' grades and conversations the teacher had with other teachers. Students were then asked to imagine a conversation with the new teacher, who would advise them whether they could choose the engineering subject. The students also received a brief description of what engineering entailed. After this part of the instruction, students were divided into three groups, each receiving different types of advice from the new teacher. The first group, the "personal" group, was told, "You can choose this subject because you are very smart." The second group received "process" feedback: "You can choose this subject because you work very hard." The third group was the control group, which received feedback but only heard, "You can choose this subject." Students were asked to rate on a five-point Likert scale how likely they would be to choose the engineering subject. Students who received personal feedback rated the likelihood of choosing engineering higher than students in the process group and the control group. The difference between the process and control groups was not significant. No gender differences were found in the impact of feedback on engineering, meaning that boys and girls responded similarly to feedback.

Mujtaba & Reiss (2014) found an effect of the construct “Pressure to study physics” on the intention to include physics in the self-chosen subject package. When comparing students who fell into the lowest quartile for this construct, the intention to study physics was significantly lower than for students who fell into the highest quartile. In a sub-analysis of the individual items, a significant effect was found for the item "My teacher thinks I should continue with physics after earning my GCSEs." Again, a lower score on this item was associated with a lower likelihood of choosing physics after the GCSEs.

Only 12.3% of students who answered the open-ended question “Who or what influenced your interest in a STEM career?” spontaneously mentioned the influence of teachers (Franz-Odendaal et al., 2016). A binary logistic regression that included the relative influence of teachers, participation in intensive STEM activities, and the degree of STEM competence described by students showed that students who mentioned teachers as an influencing factor were less likely to be interested in a STEM career.

Starr, Ramos Carranza & Simpkins (2022) examined the construct "STEM-support by teachers" with 22 questions, which included how often students talked with their teachers or school counselors about

STEM subjects and the quality of the teacher. Students who indicated an interest in a STEM career in the 9th grade were more likely to maintain their interest compared to switching to "no interest in a STEM career" if they received STEM support from teachers. STEM support from teachers did not influence students without university-educated parents to switch from no interest in a STEM career in 9th grade to interest in 11th grade. For students with university-educated parents, however, a positive, significant effect was found on increased interest in a STEM career if the student received STEM support from the teacher.

Integrated STEM Education

Dunlop et al. (2019) reflected on the results of a three-year program that investigated the influence of human spaceflight on primary school students' (ages 9-11) attitudes toward STEM subjects. This qualitative study found that the relationship with external STEM experts was important in forming an interest in STEM careers. In several classes, it was observed that after contact with an expert, such as a scientist studying coral, children became interested in a specific career. In this case, children became interested in becoming a scientist or marine biologist after the contact. Approaches to teaching and learning science were important to children. For example, children reported enjoying watching the launch but finding follow-up work (especially factual writing) less interesting. This negative view of writing was common in schools, and some teachers were critical of using science as a vehicle for English and math. The influence of different types of STEM-related field trips on interest in STEM was not quantitatively analyzed.

El Mawas et al. (2022) examined the effect of “Final Frontier,” an interactive, educational computer game for primary school children in Slovakia (ages 10-12) and Ireland (ages 9-10). The game was developed by the NEWTON Project consortium partner, National College of Ireland. In the computer game, children learned about space and the solar system over two lessons. Students played independently, with the teacher only being involved in case of technical problems. In Slovakia, the effect of the program on the question “Science lessons/using NEWTON have made me more interested in STEM” was only examined for the program group through pre-posttest analysis. The score on this question increased from 3.11 on a 5-point scale measured before the program to 3.47 after the program. In Ireland, the score after the program changed little compared to the score before the program (before the program: 3.93, after the program: 3.83). In Ireland, the control group first received information about space and the solar system in the usual way, through a teacher using PowerPoint. They then received the Final Frontier lessons. The control group's score dropped significantly after completing the Final Frontier lessons (before the Final Frontier program: 3.93, after the program: 3.03).

Archer et al. (2013) investigated the effect of an extensive six-week STEM program for students in the 9th grade in England. The program was developed by the STEM coordinator of the school where the program was implemented and included working on a STEM project with a multidisciplinary focus, field trips, and a STEM "speed networking" event where students met six different STEM professionals (for the entire program, see Archer et al. 2013). Comparing the scores measured before and after the program showed that although more students agreed with the statement "I want to become a scientist" (from 12% before to 19% after completing the program) and "When I grow up, I want to work in science" (from 39% to 49%), the latent variable "ambitions in science" did not significantly change (average before: 15.43 out of 25, average after the program: 15.96).

The program by Kang et al. (2023) lasted 2.5 years, encompassing the entire lower secondary school, and took place entirely during STEM lessons. The program consisted of 25 scenarios, designed in multi-stakeholder cooperation, and then evaluated by students. The scenarios were inspired by and then integrated into physics, chemistry, biology, and geography. A scenario focused on a specific STEM profession, such as transport planner, and included a social science problem that needed to be solved. Specific activities that students could perform in class were linked to the STEM profession. This international quasi-experimental study included three schools per country (Finland, Estonia, and Germany). Data from the different countries were combined into one dataset. In each school, some classes received the program, while other classes received regular education. The program group had significantly more interest in science and considered it more important compared to the control group. The program group also scored significantly higher on "ambition for a STEM career." No differences were found between the program and control groups in how prepared students felt by the school for the STEM skills needed for a STEM career. Finally, students were asked if they felt informed about which STEM careers exist and what steps a student could take if they wanted a STEM career in the construct "information." The program group scored significantly higher than the control group.

The teaching materials used by Kovarik et al. (2013) were developed through an iterative process guided by the principles of Understanding by Design

(Wiggins & McTighe, 1988) and "constructivist" perspectives. In this perspective, it is assumed that students build their understanding based on previous experiences and construct conceptual pillars on which they can integrate newly learned lessons. The introductory bioinformatics curriculum introduced students to a collection of bioinformatics tools, examining the ethical issues surrounding genetic testing. The advanced curriculum, "Using Bioinformatics," built on the lessons from the introductory curriculum and included additional informatics resources to teach concepts related to species diversity and evolution. In both the introductory and advanced curricula, each lesson featured an individual who worked with bioinformatics or whose work was made possible by bioinformatics. In the concluding career lesson, students studied a career in depth and wrote their own resume to document their bioinformatics experience. Students in the introductory unit did not show a significantly higher score on the statement "I see myself working in a career that involves scientific information." For the other program group, where students were part of the Advanced Curriculum Unit, a significant increase was measured with an increase of 1.3 points.

Extracurricular STEM Activities

In the longitudinal cohort study, Banerjee (2017) evaluated the impact of STEM enrichment and enhancement activities on the choice of STEM subjects "post-16" based on data from 631,267 young people. This is the point when students in England can influence the composition of their subject package. No direct positive effect of participation in these activities on students' STEM subject choices post-16 was found. The findings were similar for all students, regardless of their socioeconomic status or ethnicity. Students registered by their school for STEM enrichment and enhancement activities each year had no greater chance of continuing to study STEM subjects than their peers post-16. It is important to note that the classification into the program group was based on information from the "National Pupil Database." This means that if a school reported offering extracurricular STEM activities from the 2007/2008 school year to the 2013/2014 school year, the school was classified as a "program group" school. The control group consisted of schools for which it was unclear from the database whether they offered STEM activities throughout the entire period. Therefore, it is possible that program group schools were also included in the control group. Additionally, it cannot be determined with certainty whether students from program group schools actually participated in the offered STEM activities.

In the study by Starr, Ramos Carranza & Simpkins (2022), no significant relationship was found between participation in extracurricular STEM activities and the retention of STEM career expectations among students with non-university-educated parents. Students with university-educated parents who started 9th grade with STEM career expectations were more likely to maintain their STEM career expectations in 11th grade, compared to switching to non-STEM careers, if they participated in extracurricular STEM activities. For students with university-educated parents who started 9th grade with non-STEM career expectations, extracurricular STEM activities were not significantly related to switching to STEM career expectations.

Franz-Odendaal et al. (2016) found a significant relationship between students who reported participating more frequently in intensive STEM activities and those who reported an interest in a science career in the future. Siani & Dacin (2018) also found a positive relationship between participation in extracurricular STEM activities and interest in a STEM career. They found that students who participated in extracurricular STEM activities in their final year with a mandatory subject package in high school were twice as likely to consider a career in STEM compared to classmates who did not participate in these activities.
In the study by Kompella et al. (2020), 10- to 16-year-olds were invited via flyers and social media to participate in the "Present your PhD" program. PhD students who presented their research in the program received prior instruction. On the day of the program, PhD students from various STEM fields presented their research, after which participants in a group developed a whiteboard poster on the topic and presented it to the other attendees and parents after 40 minutes. The program's effect was investigated with a pre-post retrospective questionnaire. A significantly higher score was found for the score measured after the program compared to the score before the program for the statements "I want to take more science classes" and "I want to become a scientific researcher when I grow up." The difference in score for the statement "I want a career in STEM" was just not significant.

The study by Post & Walma van der Molen (2014) was conducted among Dutch primary school children. Six schools that already participated annually in a local project promoting technology through company visits were included in the program group. The control group consisted of seven schools that did not participate in this project and matched the program group in background characteristics. A total of 14 technology-oriented companies from the area volunteered to participate in the company visits. Teachers organized and prepared the visits in collaboration with representatives of the participating companies. Two company visits were scheduled for each class. Additionally, teachers prepared several learning activities that they could do in the classroom before the company visits. To prepare for the company visits, children participated in a school competition by completing two assignments at school: (1) designing and building the most effective (miniature) windmill and (2) creating the best computer model drawing. All final designs were displayed in a local exhibition center, where the children, their teachers, and parents could view them at the end of the company visits. Each assignment was awarded one school as the winner. Each class visited two different companies that had prepared a tour and an authentic design activity where the children worked individually in the company workshop under guidance and with the help of specialists. For example, welding different materials together to make more durable structures. In all company tours, children were allowed to take home the miniature designs they worked on during their visit to show their families. In the evening, parents were invited to visit the same companies their children had visited earlier that day and to attend the public announcement of the winning windmill and computer model drawing at the local exhibition center. Surveys were conducted one month before and one month after the company visit. Children responded to statements using a 4-point Likert scale. The analysis showed that the program had no effect on students' interest in working in technology in the future compared to the control group. There was also no effect on perceived relevance and difficulty. Additionally, children scored significantly higher on perceived enjoyment before participating in the program compared to the score given after completing the program. No significant interaction was found between time and the program group. The authors conclude in the discussion: "*The results indicated that the image and attitude of children largely remained unchanged by the company visits, a finding that could be explained by the observation that the level of preparation at school, follow-up activities, and the degree of teacher involvement during the visits were generally low. Moreover,* *observations during the visits revealed that the activities at the technical companies were mostly 'hands-on' and stereotypical (e.g., working with machines)*."

Henriksen, Jensen & Sjaastad (2015) conducted a retrospective study in which students who had already chosen a STEM degree were asked which programs or activities had influenced their educational choice in the past. Students could indicate whether they had encountered certain extracurricular activities (such as films or computer games) or targeted recruitment efforts (such as university websites) before choosing a STEM degree. They could also rate on a 4-point Likert scale to what extent a program, activity, or recruitment effort (hereafter referred to as activity) had inspired them to choose the degree. For the current literature review, only the results for students in Engineering, MSc in Engineering, and Computer Science were reported. For a complete overview of the results, including degrees in Science, Pharmacy and Biological Laboratory Sciences, Mathematics, and Physics, see Henriksen, Jensen & Sjaastad (2015). Both an average score and the percentage of students who rated the activity with a 4 ("great degree of inspiration") were calculated for the activities. Notably, popular science TV channels/programs consistently scored relatively high for all three degrees (Engineering: M=2.5, %4=22, MSc in Engineering: M=2.6, %4=21, Computer Science: M=2.1, %4=12). Visiting a science museum or center consistently scored on the lower side (Engineering: M=1.5, %4=2, MSc in Engineering: M=1.7, %4=3, Computer Science: M=1.4, %4=1). Computer games seem to be an inspiration for students who chose computer science but to a lesser extent for the other two degrees (Engineering: M=1.3, %4=2, MSc in Engineering: M=1.2, %4=1, Computer Science: M=2.4, %4=20). Regarding targeted recruitment efforts, only responses from students who received this type of recruitment were included in the calculation. University websites consistently scored the highest (Engineering: M=2.6, %4=18, MSc in Engineering: M=2.8, %4=28, Computer Science: M=2.7, %4=25). Visiting a university also scored relatively high for MSc in Engineering and Computer Science, although this was less evident for Engineering (Engineering: M=1.8, %4=8, MSc in Engineering: M=2.2, %4=17, Computer Science: M=1.9, %4=12). Visits by companies to schools consistently scored low (Engineering: M=1.5, %4=3, MSc in Engineering: M=1.4, %4=2, Computer Science: M=1.3, %4=1). Likewise, company visits consistently did not score significantly high (Engineering: M=1.8, %4=9, MSc in Engineering: M=1.7, %4=6, Computer Science: M=1.5, %4=3). Finally, targeted recruitment efforts by a school counselor did not score highly (Engineering: M=1.5, %4=4, MSc in Engineering: M=1.4, %4=3, Computer Science: M=1.4, %4=2).

Stoeger et al. (2021) reflected on the online mentoring program CyberMentor for girls in Germany, which has existed for nine years. Girls could sign up for free in secondary school (ages 11 to 18). The mentors were women with a STEM degree at the university level who worked in a STEM profession or were pursuing a master's degree in STEM. Participants and mentors communicated with each other for at least 30 minutes per week on various topics, including STEM, curricular and extracurricular activities, and their daily experiences. All participants spent at least one year in the program. At the end of each mentoring year, participants and mentors could enroll for another year of participation. Several mentoring formats were applied during the nine years the program was accessible. From 2009 to 2011, the program used a one-on-one mentoring format. During the 2012 mentoring year, the format was changed to a "many-to-many" group mentoring. Communities of six people were formed, consisting of three students and three mentors without explicit one-on-one assignments. From 2013 to 2017, the program adopted a hybrid mentoring format that combined the one-on-one mentoring and many-to-many formats. Communities of four people were formed, consisting of two mentor duos; each pair reflected a one-on-one mentor-participant assignment. Participants indicated on a 6-point Likert scale how well they could imagine choosing a university STEM degree, selecting a STEM subject for a track or course at school or university, or pursuing a career in a STEM field. These questions were summarized into "STEM choice intentions." Latent growth models for the three separate mentoring formats were analyzed to determine the pre/post effect. In none of the unconditional growth models of STEM choice intentions was a significant change in score measured during the program year.

In the long-term follow-up study by Stoeger et al. (2023), former participants of the Stoeger et al. (2021) study who were now pursuing a higher education or career were approached. The percentage of women who had chosen a STEM or STEMM (STEM including Medical Sciences) was calculated for the former program group. This percentage was also calculated for a "matched control group," consisting of women who had registered for CyberMentor in the past but did not participate. Finally, the percentage was calculated for a control group consisting of the German population of female first-year university students, as reported by the German Federal Statistical Office. The percentages show a significant difference in STEM career choice between the control group and the other two groups, but not between the matched control group and the program group (control group: 26.8%, matched control group: 48.8%, program group: 51.2%). The same effect is seen for STEMM career choice (control group: 43.7%, matched control group: 58.1%, program group: 61.7%). When the choice for a degree or career in computer science and engineering is examined separately, only a small difference is seen between the three groups (control group: 18.3%, matched control group: 21.1%, program group: 24.9%).

Social Context

Hübner et al. (2017) investigated an educational reform that was implemented in Germany in 2002. This reform limited the freedom of students in secondary school to choose a basic or advanced subject. Before the reform, the time spent on a basic subject was three hours per week, compared to five hours per week for an advanced subject. A student typically chose two advanced subjects and six basic subjects. After the reform, all students were required to take five subjects from specific areas (e.g., German, mathematics, foreign languages, science) for four hours per week. In addition to these mandatory subjects, students took other subjects, such as art or social studies, for two hours per week per subject. Data from students in their final year of secondary school from 2002, before the reform, and 2006 were compared. For both cohorts, the field of study at university was determined two years after graduation. This was classified as STEM when the student studied mathematics, engineering, computer science, or physics. The reform had no significant effect on the number of students entering STEM programs, even when interaction for gender or school type was included. Although the overall score for math skills did not significantly change after the reform, a significant cohort × gender interaction was measured. This was mainly due to a higher average score for women after the reform, while men's performance did not differ before and after the reform. Contrary to expectations, women had a significantly lower score for math self-concept after the reform than before. Men's math self-concept did not differ. The interaction for cohort × gender was therefore statistically significant for math self-concept.

Kiselova & Gravite (2017) also investigated the effect of an educational reform, this time the National Development Plan of Latvia for 2014-2020. The plan identified the development of science and technologies as a determining factor for economic sustainability, the welfare of the Latvian society, and the preservation of the environment and natural resources. The reform focused, among other things, on new state standards developed for all levels of education, a mandatory centralized math exam for secondary school graduates, reallocating funding from the state budget in favor of STEM areas in higher education, and implementing a "Science and Mathematics" project (funded by the European Structural Funds) in both primary and secondary schools. The researchers compared PISA data from 2006 with PISA data from 2015. Fifteen-year-old students were asked, among other things, what profession they were interested in. Science-related professions were grouped as scientific & engineering professions, health professions, information and communication technology specialists, and science-related technicians and craftsmen. Only 20% of Latvian students showed interest in choosing these professions in 2015, compared to 17% in 2006. This increase was caused by a growing interest in health professions. Interest in a career in health increased by 5.4%, (from 3.9% in 2006 to 9.4% in 2015), while interest in science and technology decreased from 8.5% in 2006 to 7.2% in 2015. The interest of Latvian students in a career in engineering or related professions did not change over time. Data from the Higher Education Department of the Ministry of Education and Science showed that the number of engineering students did not significantly change and even showed a slight decrease (13,945 engineering students in 2009 compared to 12,535 in 2015). The number of students graduating from an engineering program also did not significantly change (2,596 in 2013 compared to 1,963 in 2016). The results of this study should be approached with caution; due to the brief period between the start of the reform in 2014 and the analysis with data from 2015, it is possible that the effects of the reform have not yet (fully) materialized.

Stoet & Geary (2018) found in an analysis of international PISA data that gender differences in STEM graduation rates and intra-individual gender differences in relative strength in science and reading increased as gender equality in a country increased. To better understand this result, the researchers conducted a mediation analysis, including Overall Life Satisfaction (OLS). OLS was included as a measure of overall living conditions; it is a good indicator of economic opportunities and hardships and social and personal well-being (Pittau et al., 2010). In more egalitarian countries, overall life satisfaction was higher. The researchers hypothesized that low prospects for a satisfied life might motivate girls to focus more on science in school and choose a relatively better-paid STEM field as adults. A mediation analysis showed that OLS indeed partially mediated the relationship between gender equality and gender differences in STEM graduation rates. The effect of the direct path in the mediation model was statistically significant.

Conclusion, Discussion, and Relationship of Findings to the Development of Technology Promotion in the Dutch Context

The studies discussed offer valuable insights into the factors that influence the choice of STEM (Science, Technology, Engineering, Mathematics) education and careers. In this chapter, we translate the findings, where possible, into tangible advice for the further development of Technology Promotion among students (ages 9 to 15) in the Dutch context. Critical remarks are also made regarding current research where necessary.

Conclusions Regarding the Development of Technology Promotion Programs

Self-efficacy

Research indicates that the self-efficacy experienced by the student concerning a STEM subject or subjects is important throughout the entire 'pipeline.' Self-efficacy is often measured by asking the student if they have confidence in their own skills or how good they perceive themselves to be in a STEM subject, such as mathematics, physics, or chemistry. Self-efficacy is therefore clearly different from the objective score for skill. One can imagine that an explanation of what a technical profession entails or an extracurricular STEM activity, such as building robots, does not always improve the lack of self-efficacy. In fact, a technical explanation of the actions performed by an employee in a technical company, or the failure of a technical experiment, can further decrease self-efficacy. Attention to this determinant is frequently seen in research.

Suggestions for Practical Application

When determining the content of a program, attention to positively influencing self-efficacy could be one of the basic principles. For instance, it might be interesting to invite not only an employee of an organization who has followed a technical education but also a lateral entrant during a company visit. Attention to accessible teaching materials, with different versions allowing differentiation in difficulty without emphasizing that a student cannot achieve the difficult level, can also prevent a decline in self-efficacy. A specific program aimed at improving self-efficacy is also a possibility.

Skills and Relative Strength

Being skilled in STEM subjects appears to increase interest in STEM but does not guarantee a choice for STEM. Students who are good at, for example, mathematics or chemistry, may be even better at economics or biology and therefore choose a profession in that direction. Students choose subjects where the chance of success is high, and the homework load is low. Finally, it is important to acknowledge that in the Dutch school system, a student usually chooses all subjects at one level. If a student chooses a VWO profile but could only manage a HAVO or VMBO level for the beta technical subjects, they may not choose them at all.

Suggestions for Practical Application

When one wants to directly influence students' skills, it is important to start at an early age and to offer accessible support at various times for students who are interested in beta technology but may not naturally have the greatest aptitude for these subjects.

Familiarity with STEM Professions and Affective Attitude

Both international and Dutch research shows that students often do not know what a beta technical profession entails, what is needed to pursue a career in this sector, and how the beta technical sector contributes to relevant societal issues. To positively influence students' knowledge, both integrated STEM activities and extracurricular activities can be considered. The literature review shows that every program falling under the aforementioned categories is unique. Moreover, the way a program is developed, the content, the duration, and the person implementing the program can both positively and negatively influence its success.

Suggestions for Practical Application

In programs aimed at informing students about beta technical professions or studies, it is important that the stereotypical ideas that students have about working in technology are not confirmed, as happened in the only Dutch study that evaluated the effect of a program in this literature review (Post & Walma van der Molen, 2014). Preferably, a program is offered in which the likelihood of resonating with the target group is higher and emphasizes the importance of technology for society. For example, in the effective program by Kompella et al. (2020), students from technical studies were invited to discuss their graduation projects or research with students, after which students themselves transformed this information into a presentation. Inviting students who are being trained for a profession related to a sector strongly connected to societal interests, such as healthcare, aligns with the needs of a large group of students. A guest lecture from a student MBO healthcare technician or MSc technical physician could align with this proposal. Students pursuing a study related to technology but whose work is not stereotypically “hands-on” may also potentially improve attitudes toward technical professions in this specific target group. The MBO course for mid-level management in construction is a good example here. Research among students who had already chosen a beta technical course showed that university websites were an important factor influencing their choice. For educational institutions as well as employers' websites, it is advisable to clearly communicate the societal goals supported, where applicable.

Instrumental Attitude

Various studies show that students who choose a STEM subject more often indicate that they believe a beta subject or profile will help them in a future career. However, what seemed important factors in choosing a career path five years ago may not be so now. Easily finding a job or earning a good salary are no longer unique advantages of choosing a job in beta technology, as three-quarters of Dutch entrepreneurs are currently experiencing a labor shortage (Centraal Bureau voor de Statistiek, 2023).

Suggestions for Practical Application

It is important to structure beta technology in such a way that the “returns” of working in beta technology outweigh the relative “costs” a student incurs to work in this sector. Both the benefits and costs can be adjusted.

What is seen as “return” can differ per generation, and it is essential to constantly update this insight. For example, the Randstad Workmonitor of January 2024 shows that employees, especially Gen Z, place more emphasis on personal values and a healthy work-life balance at the expense of traditional career goals such as financial growth and vertical advancement (Randstad, n.d.). Providing good opportunities for maintaining that balance, such as flexible working hours, extra vacation days, or the option of unpaid leave, are ways to appeal to the new generation of workers. Highlighting opportunities for personal work involvement through participation in projects, development with a development budget, growth opportunities within the sector, or transitioning from beta technology to other sectors may lower the threshold for choosing a career in beta technology.

On the cost side, one could consider the homework load in secondary school, which is perceived as higher for beta profiles. Is it necessary for all beta technical courses that a student studies this, as perceived by the student, more demanding beta subject throughout the entire upper secondary school? Or are there possibilities for a “crash course” in beta prior to a course, where a student can catch up on the beta knowledge relevant for a specific beta technical course?

Integrated STEM Education vs. Extracurricular STEM Activities

When determining the content of a program, it is of course important to first determine the goal and target group. Ait Moha, Muller & Thijssen (2019) divide students into five segments, each with a different level of conviction to choose STEM. One could choose to focus on the students identified as low-hanging fruit (segment "Innovators") and try to optimize the number of students not only interested in choosing technology but also actually making that choice. Parents play a key role for them.

At the other end of the spectrum are the Social Implementers, who show the lowest level of interest. External influences have little grip on them. In the Dutch, individualistic culture, the opinion and needs of a child are often central. One can imagine that parents of children in this segment, with such low intrinsic motivation and a low perception of their ability in technology, do not see any entry points for influencing the choice of education. It is also questionable whether these students would sign up for extracurricular activities, such as the national initiative Girls' Day (Sterk Techniekonderwijs, 2024).

Suggestions for Practical Application

To push the doubters in the already interested Innovators segment over the line, a program aimed at parents, such as the effective program by Harackiewicz et al. (2016), could be considered. Here, mothers were informed about the positive impact of choosing a STEM subject in upper secondary school on their child's future. In addition to substantive information, the mothers also received information on how to initiate a conversation with their child. If one attempts to re-engage the disengaged Social Implementers, a program embedded in the lessons offered by the school may be a better entry point.

Conclusions Regarding the Development of Technology Promotion Research

Limitations in Quantity, Quality, and Applicability of Existing Research

The primary goal of the current literature review was to explore possibilities in the international literature to identify potential "blind spots" regarding successful Technology Promotion programs. The amount of research focused on the predefined target group specifically related to the STEM field is limited. Particularly, delineated research for primary school students is scarce; only two studies exclusively included children in primary education (Dunlop et al., 2019, Post & Walma van der Molen (2014)). The limited number of studies combined with the great diversity in purpose (exploratory vs. confirmatory), target group, and design made generalization not well possible. As a result, conclusions are limited to answering the question "what possibly works?" and it is not possible to answer the question "what works best?".

The methodological quality of the included studies was assessed as predominantly "low" or "moderate." Causes for this include, for example, small group size, the absence of a control group, the sole use of a qualitative evaluation, and the use of only basic statistical tests. Based on these findings, it can be concluded that research on Technology Promotion, especially when compared to, for example, medical interventions, is still in its infancy. Therefore, lessons cannot be drawn solely from research in the international field. A developmental step will also be needed nationally to supplement the Body of Knowledge on this topic in a qualitatively strong manner.

Through the current literature review, the challenge of identifying applicable and qualitatively good research emerged. Some studies, such as those in Latvia, may not have had enough time to assess the long-term effects of educational reforms. This underscores the need for long-term evaluations. The recommendation is therefore to conduct longitudinal studies to follow the effects of Technology Promotion on interest in technology over several years.

Suggestions for Practical Application

To enable comparison of programs and generalization in conclusions, a larger amount of conducted research should be drawn upon. It is essential to improve the accessibility of research already conducted in the Dutch context and to centralize, where possible, the results of evaluations of conducted research and the accompanying information and teaching materials.

Longitudinal cohort studies are a valuable resource, and this type of research is also necessary to explore trends in choice behavior among children and adolescents. The execution of this type of large-scale and long-term research cannot be expected from independent researchers or project leaders. The setup is too complex, and the financing too costly. However, this does not mean that it is impossible for them to use this type of data. Consortia and research institutions do conduct such research, where data is often available on request. Sometimes a financial contribution is required, in other cases, data can be requested for free. For example, the website of the Nationaal Regieorgaan Onderzoek (NRO) refers to several other initiatives to find articles, thematic overviews, practical guidelines, and answers to educational questions (Nationaal Regieorgaan Onderwijsonderzoek, n.d.(a)). The NRO also conducts its own research, the data of which can be requested, and they refer to other studies in which the entire Netherlands participates (Nationaal Regieorgaan Onderwijsonderzoek, n.d.(b)).

Research in the Dutch Context

Much research has been conducted on interest in "STEM," where outcome measures often do not distinguish between technology/engineering and the other components; science and mathematics. For example, STEM professions also include doctors and scientific researchers, which is not the target group for the current research assignment. The influence of skills and self-efficacy is primarily studied for mathematics and science. Research by Siani & Harris (2023) shows that the level of self-efficacy in mathematics and science does influence the level of interest in a career in mathematics and science, but not in a career in technology/engineering. The effect of self-efficacy in different STEM subjects on technical professions and technology should be made separately visible. This finding argues for an expansion and strengthening of national research.

The studies include data and reforms from Germany, Latvia, and international PISA analyses. Cultural, educational system, and policy differences between these countries and the Netherlands may limit the direct applicability of the findings. For example, the setup of the choice process concerning subjects in secondary schools is fundamentally different in other countries than in the Netherlands. In England, for example, one can choose per subject for A-level or not A-level. In the Netherlands, students cannot choose the level that suits them per subject. When a student scores VMBO for core subjects, such as Dutch and English, it is often not possible to follow biology and physics at HAVO level, for example. In the Netherlands, if you want to choose chemistry, you usually also must choose biology or physics in the Nature & Health (N&G) or Nature & Technology (N&T) profile. Schools can also choose to impose additional requirements before a student can choose an N-profile in the upper secondary school (Landelijk Aktie Komitee Scholieren, 2024). For example, Comenius College requires HAVO and VWO students who want to choose an N&G or N&T profile to obtain at least a 7 in chemistry, physics, and if applicable, mathematics (if choosing mathematics B). Additionally, students must also receive a positive recommendation from teachers. If students receive a negative recommendation from the teacher for two of the three subjects (mathematics B, chemistry, or physics) despite achieving a 7.0 in all subjects, they can no longer choose the N&T profile. These rules were established because "despite teachers advising them against choosing an N-profile, students in the past persisted. In practice, it is seen that students still choose a different profile during the year. Some students persist longer but still do not achieve a passing grade on the final exam. To prevent this situation, a change in the promotion regulations has been included" (Comenius College, 2024a, Comenius College, 2024b). For the other profiles, no norm is applicable to the profile choice in upper secondary school. It is possible to choose a different profile and select chemistry as a separate elective, but only if the school offers it (Qompas Profielkeuze, 2024). One can imagine that the threshold to choose a technology profile and the degree of influence of behavioral determinants can therefore differ both in the Dutch context and even per school. Therefore, before implementing a program within the framework of technology promotion, it is important to map out specific environmental factors.

In addition to the differences in the educational system setup, cultural influences can also have a significant impact on children's decision-making behavior. For example, European Dutch society is predominantly seen as a society with more individualistic characteristics (Hofstede & Minkov, 2017), compared to a society with more collectivist characteristics, such as the Caribbean Netherlands (Bonaire, Sint Eustatius, and Saba) (Tse, 2017). The cultural-ecological model of Kağitçibaşi (1996) illustrates the variation in parenting goals between individualistic and collectivist societies. In collectivist cultures, the focus of parenting is on dependence and obedience. Here, parents often prefer an authoritarian parenting approach, requiring children to show respect and obey (Eldering, 2008). On the other hand, parenting in individualistic cultures encourages independence and self-assurance in children. Due to the less close family ties and social relationships, the emphasis is more on individual needs. This leads to a greater emphasis on personal autonomy. Parents in individualistic cultures tend to have a permissive parenting style with few established rules, where the preferences and needs of the child are central, and where children often have a say. This is also evident in the survey by Platform Talent voor Technologie, which shows, among other things, that bi-cultural students find it more important that their parents can be proud of their career choice compared to students whose parents were both born in the Netherlands (63% vs. 58%). For them, a job with prestige is also more important (33% vs. 29%) and a high salary (77% vs. 71%).

Suggestions for Practical Application

Thorough research in the Dutch context is preferred. However, there are few public documents available. The PISA survey and TIMMS survey are also conducted in the Netherlands. However, the questionnaires used are limited in scope and primarily aimed at scoring mathematics, chemistry, and language proficiency.

Analysis

The way data is analyzed and presented determines the conclusions drawn. The literature review conducted for the current assignment revealed that statistical analysis often lacked. Many results were noted descriptively. In descriptive research, observations are documented, but causal relationships cannot be well established. By not considering the influence of other factors and not correcting for biasing factors, correlations may be suggested where they may not exist. For example, in the research by Platform Talent voor Technologie (2023), it is mentioned that teachers more often give negative advice to students with a bi-cultural background and students with little confidence in technology. What is unclear is why teachers more often give negative advice to bi-cultural students. For example, if it turns out that bi-cultural youth, on average, score lower for beta technical subjects, it could well be that this explains why this group more often receives negative advice. The analysis by Platform Talent voor Technologie (2023) does not clarify whether the higher number of negative recommendations to bi-cultural students is independent of the skills or interest of the individual student.

Suggestions for Practical Application

Both exploratory and confirmatory research needs attention to the interrelationship between explanatory factors. This can be quantitatively analyzed through statistical tests. If this is not possible, then a mixed-methods study is a low-threshold second choice, where striking results in the data are discussed with the participants of the study. This can shed light on underlying mechanisms.

Data Storage

Research involves costs. Conducting research not only costs the research institution money and time, but participants also spend their time. Respectful treatment of the participant involves not only collecting and storing data safely but ideally also making it available for reuse later. For the current research assignment, Platform Talent voor Technologie was willing to share the raw data from the Platform Talent voor Technologie (2023) survey. In this rich study, over 1,000 secondary school students were surveyed. Contacts at Platform Talent voor Technologie (PTvT) were willing to share this information, for which we are grateful. Unfortunately, it turned out that they could only find publicly available pieces, as the researchers involved in the study were no longer employed at PTvT. In addition to this study, PTvT had another large-scale study (n = 1,472) conducted by Motivaction (Ait Moha, Muller & Thijssen, 2019). PTvT was also willing to provide this data for the current research. However, a bottleneck arose here as well; unfortunately, PTvT contacts could only share the percentage of responses per answer category for specific questions. The results were not stored per participant, making it impossible to investigate the influence of personal factors on choice behavior. This illustrates the importance of properly storing, documenting, and keeping data available for follow-up research and knowledge building.

Suggestions for Practical Application

To enable data reuse, participants should be given the option when participating in research to also make their data available for future research. The raw data file must also be preserved. A raw data file contains unprocessed, unfiltered data collected during the study. When an organization conducts its own research, a clear protocol is necessary in which agreements regarding data storage are described. These usually include agreements about the transfer of raw data files when researchers leave the organization. If an external research agency conducts research, it is important to make agreements in advance about what this raw data file should look like. In addition to permission for the use of data for other research, participants can also be asked for permission to be contacted again for future research. This only concerns permission to be approached, where participants can decide at each new request to participate in research whether they want to participate. Future researchers who wish to enrich the dataset or conduct other research within the same target group can build on the efforts of their predecessors.

Valid Measurements

In the design of the research, many choices are already made that can influence the direction and quality of the result. One example of a factor that can negatively influence the design is confirmation bias. A researcher often has their own conviction, or hypothesis, before starting a study. The risk arises that "the usual suspects" are asked about or that issues the researcher prefers not to report are explicitly not asked about. For example, one could imagine that children and adolescents are asked the statement "If I went to museums or organized technology outings with school more often, my interest in technology would increase." A positive answer might, perhaps incorrectly, confirm the hypothesis that visiting museums or other organized technology outings contributes positively and should therefore be invested in continuously.

Furthermore, it is important to measure the influence of a behavioral determinant, such as self-efficacy, in a valid manner. What was striking is that what is considered "self-efficacy" can vary greatly between studies. For example, Mujtaba & Reiss (2014) examined whether students thought they needed help with physics. Kovarik et al. (2013) included in the construct self-efficacy the question, "I understand how databases store biological information for research." This could also be seen as a statement more appropriate to the behavioral determinant "knowledge." Additionally, it was one of the goals of the Kovarik et al. (2013) program to teach students more about this specific topic in a bioinformatics curriculum. One could therefore question whether such a statement is appropriate in an effect evaluation or is better suited in a process evaluation. For the introductory group, a significant increase in the self-efficacy construct was indeed measured; in contrast, there was only a negligible increase in the statement “I see myself working in a career involving scientific information.”

Suggestions for Practical Application

The use of previously used, preferably validated, questionnaires to determine the influence of self-efficacy or other behavioral determinants is therefore recommended, as is the use of multiple questions that together form a construct score. The difference between using open and closed questions is also crucial. By asking students in an open-ended question what influences their choice of technology, space is given to discover previously unidentified determinants. A single open-ended question alone does not seem to provide a complete picture of the possible influencing factors. For example, in the study by Franz-Odendaal et al. (2016), students barely mentioned the influence of parents on the choice of STEM. However, research by Harackiewicz et al. (2016) showed that students are indeed influenced in their choice by the perceived utility experienced by mothers regarding STEM and the number of conversations students had with their parents about STEM. A suggestion for a mix of an open-ended but still directional question could be, for example, the following question to students: “Rank the different ways you encounter technology activities based on interest. Place the technology activity that most increases your interest in technology at the top, the activity that least motivates you to choose technology at the bottom.” Students choose from a list of established activities, including influences from parents, social media, study choice tests, etc. To provide even more space, a student could be offered the option to add their own options and include these in the ranking.

Limitations

Relationships Between Determinants

In current research, the relationships between influenceable student characteristics have not been extensively explored. For example, the relationship between enjoyment and skills, or skills and self-efficacy. However, the included studies repeatedly show that there is a correlation between scores on individual subjects. For example, Niepel, Stadler & Greiff (2019) found that the score on “mathematical self-concept” was strongly related to the actual mathematical performance of young people. This was also evident in the research by Franz-Odendaal et al. (2016), where a significant positive correlation was found between the ranking of a subject based on confidence and based on enjoyment for almost all subjects. This means that when a student’s confidence in a subject increases, the student also ranked that subject higher in the ranking of favorite subjects. This correlation was not found only for biology.

Focus on Beta Technology

Within the framework of the research question, which specifically aims at increasing interest in beta technology among students (ages 9 to 15), only articles addressing this specific subject were included. As a result, studies that more generally examine decision-making behavior and approaches to behavioral changes for this target group were excluded.

Epilogue

The current literature review presents several recommendations. The optimistic conclusion is that, from a behavioral science perspective, there are multiple points of reference to make Technology Promotion programs more effective by focusing on the behavioral determinants that influence educational and career choices among students aged 9 to 15. By following these recommendations, further research can yield more targeted strategies to effectively promote technology among Dutch children and adolescents, considering the specific context and needs of this target group.

Partially, this advice seems directly applicable to both existing and yet-to-be-developed Technology Promotion programs. For example, by paying attention to the influence of students' self-efficacy or interest in technology when (re)designing programs. It is important to recognize that the knowledge needed to move from the goal—in this case, strengthening self-efficacy—to the concrete and effective modification or supplementation of program materials demands a lot from project leaders and contractors. Even more evident is the "gap" between the ideal research and intervention methodology and the current reality. Not only in the Dutch context but also from the international literature, the beta-technical field still has significant development potential in terms of scientifically substantiating, designing, and evaluating research and programs aimed at improving Technology Promotion. There is a real possibility that the knowledge and skills that project leaders and contractors currently possess may not yet be sufficient to work as proposed in the various recommendations.

The desire of the clients to encourage project leaders and other contractors in Technology Promotion to adopt a new way of working, in which the above recommendations are applied, will need to be expressed in a suitable plan to motivate and facilitate the target group (project leaders and contractors) to make the desired behavioral adjustments. In the second part of the current report, the steps that the clients need to take to make the implementation of the new working method a success are discussed in detail.

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Appendix 1. Search Terms and Search Strings for Literature Review

Search	Database	Date	Search String and filters
1.1.	Pubmed	18-07-2023	(((((((("primary school") OR (children)) OR ("primary education")) OR ("elementary school")) OR ("childhood")) OR ("pre-adolescents")) OR ("Child"[Mesh])) OR ("Schools"[Mesh:NoExp])) AND ("science, technology, engineering and mathematics")) AND (((career) OR (job)) OR (work))
1.2.	Pubmed	27-07-2023	((((((highschool) OR (youth)) OR ("Adolescent"[Mesh])) OR ("Adolescent Development"[Mesh])) OR ("Puberty"[Mesh])) OR ("early adolescents")) OR ("high school")) AND (("science, technology, engineering and mathematics") OR ("STEM career")) Filter: 5 years
2.1.	ERIC	19-07-2023	(((("Denmark" OR "Danish" OR "Estonia" OR "Estonian" OR "Finland" OR "Finnish" OR "Iceland" OR "Icelandic" OR "Latvia" OR "Latvian" OR "Lithuania" OR "Lithuanian" OR "Norway" OR "Norwegian" OR "Sweden" OR "Swedish" OR "North Europe" OR "Northern Europe" OR "North-European") OR ("Andorra" OR "Andorran" OR "Austria" OR "Austrian" OR "Belgium" OR "Belgian" OR "France" OR "French" OR "Germany" OR "German" OR "Ireland" OR "Irish" OR "Liechtenstein" OR "Liechtensteiner" OR "Luxembourg" OR "Luxembourgish" OR "Monaco" OR "Monégasque" OR "Netherlands" OR "Dutch" OR "Switzerland" OR "Swiss" OR "West Europe" OR "Western Europe" OR "West-European"))) AND (((((((("primary school") OR (children)) OR ("primary education")) OR ("elementary school")) OR (childhood)) OR ("pre-adolescents")) OR ("Child"[Mesh])) OR ("Schools"[Mesh:NoExp])) OR ((((((highschool) OR (youth)) OR ("Adolescent"[Mesh])) OR ("Adolescent Development"[Mesh])) OR ("Puberty"[Mesh])) OR ("early adolescents")) OR ("high school")))) AND ((((("science, technology, engineering and mathematics") OR ("science, technology, engineering, mathematics")) OR ("science technology engineering mathematics")) OR ("STEM career"))) Filter: Since 2014 (last 10 years)
2.2.A.	ERIC	27-07-2023	(("science, technology, engineering and mathematics") OR ("STEM career")) AND (((((((("primary school") OR (children)) OR ("primary education")) OR ("elementary school")) OR (childhood)) OR ("pre-adolescents")) OR ("Child"[Mesh])) OR ("Schools"[Mesh:NoExp])) OR ((((((highschool) OR (youth)) OR ("Adolescent"[Mesh])) OR ("Adolescent Development"[Mesh])) OR ("Puberty"[Mesh])) OR ("early adolescents")) OR ("high school"))) Filter: Location: U.K. Filter: Since 2014 (last 10 years)
2.2.B.	ERIC	27-07-2023	(("science, technology, engineering and mathematics") OR ("STEM career")) AND (((((((("primary school") OR (children))

			OR ("primary education")) OR ("elementary school")) OR (childhood)) OR ("pre-adolescents")) OR ("Child"[Mesh])) OR ("Schools"[Mesh:NoExp])) OR ((((((highschool) OR (youth)) OR ("Adolescent"[Mesh])) OR ("Adolescent Development"[Mesh])) OR ("Puberty"[Mesh])) OR ("early adolescents")) OR ("high school"))) Filter: Location: U.K. (England) Filter: Since 2014 (last 10 years)
2.2.C.	ERIC	27-0702023	(("science, technology, engineering and mathematics") OR ("STEM career")) AND (((((((("primary school") OR (children)) OR ("primary education")) OR ("elementary school")) OR (childhood)) OR ("pre-adolescents")) OR ("Child"[Mesh])) OR ("Schools"[Mesh:NoExp])) OR ((((((highschool) OR (youth)) OR ("Adolescent"[Mesh])) OR ("Adolescent Development"[Mesh])) OR ("Puberty"[Mesh])) OR ("early adolescents")) OR ("high school"))) Filter: Location: Germany Filter: Since 2014 (last 10 years)
2.2.D.	ERIC	27-0702023	(("science, technology, engineering and mathematics") OR ("STEM career")) AND (((((((("primary school") OR (children)) OR ("primary education")) OR ("elementary school")) OR (childhood)) OR ("pre-adolescents")) OR ("Child"[Mesh])) OR ("Schools"[Mesh:NoExp])) OR ((((((highschool) OR (youth)) OR ("Adolescent"[Mesh])) OR ("Adolescent Development"[Mesh])) OR ("Puberty"[Mesh])) OR ("early adolescents")) OR ("high school"))) Filter: Location: Finland Filter: Since 2014 (last 10 years)
2.2.E.	ERIC	27-0702023	(("science, technology, engineering and mathematics") OR ("STEM career")) AND (((((((("primary school") OR (children)) OR ("primary education")) OR ("elementary school")) OR (childhood)) OR ("pre-adolescents")) OR ("Child"[Mesh])) OR ("Schools"[Mesh:NoExp])) OR ((((((highschool) OR (youth)) OR ("Adolescent"[Mesh])) OR ("Adolescent Development"[Mesh])) OR ("Puberty"[Mesh])) OR ("early adolescents")) OR ("high school"))) Filter: Location: Netherlands Filter: Since 2014 (last 10 years)

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