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# Assessing the maturity of innovation platforms

*A conceptual maturity model and a case study of TIP*


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Abstract

**Introduction:** This study aims to develop a maturity model for innovation platforms. This model is applied to the Technology Innovation Processes (TIP) platform. By using design science, a methodology for developing maturity models, and the principles of the Capability Maturity Model Integration, the research intends to provide a systematic and effective model for evaluating and improving the maturity of innovation platforms.

**Methodology:** This research employs a design-oriented approach to develop a maturity model for innovation platforms. The methodology is mainly based on Maier et al.'s (2009) guide for developing a maturity model and a maturity grid. This method involves planning, development, evaluation, and maintenance of the tool. Through a literature review, the maturity model was developed. Furthermore, the model undergoes evaluation through a single case study of TIP. Inductive results are included in the maturity grid after data analysis. Lastly, the tool is intended to be improved iteratively during the maintenance phase, which will start after this research.

**Results:** The TIP method demonstrates a boost in innovation competencies, with positive student attitudes. Challenges include the understanding of knowledge and tools, as well as the complexity of the contents and the tools. Teaching methods incorporate real-life cases and a variety of assessment methods. TIP excels in fostering a student-centric learning environment, but still faces challenges in guiding time-management. The complexity of real-life cases demands more balance to prevent poor time-management of students. Quality management is organized in a well-manner, by including stakeholder feedback. The tools that are used for TIP ask for further refinement, in order to reduce the complexity of the innovation process.

**Discussion/conclusions:** This research introduces maturity assessment criteria for innovation platforms, and therefore addresses an untouched literature gap. Theoretical implications of this research include pioneering maturity models for innovation platforms. Practical implications include the guided decision making for developers and identifying strengths and weaknesses of innovation platforms. While recognizing limitations, this research suggests that future efforts should be performed to further validate this maturity model. Managerial recommendations for the developers of TIP focus of students' learning approach, the complexity of learning materials, the social skills of students, guided time-management, and the refinement of the core tools that are used for TIP.

Preface

Before you lies the thesis: “Assessing the maturity of innovation platforms”. This thesis is the final product of my master Business Administration: Entrepreneurship, Innovation, and Strategy of the University of Twente. This thesis was written between May 25th 2023 and Januari 23rd 2024.

Saxion Enschede provided me with a challenging, but fun and interesting topic for my thesis. I would like to thank Alfons Wegdam for always providing me with the information I needed. A special thanks goes out to Alfons for providing me with spot on feedback on my project management from start to the end. Although it has not always been the easiest task, this will help me with my own personal growth in my future career.

During my thesis, I have been supported by Patrick Bliek and Maximilian Goethner as respectively my first and second supervisor of the University of Twente. Without them, my final product would not have been what it is now. Patrick has helped me to create insights and ideas, which have helped me understand the subject. Maximilian has provided me with valuable feedback on all the parts where I needed it. Although my background did not lie in Business Administration when I started this Master, they helped me write and conduct research within this field. I would like to thank both Patrick and Maximilian for this.

Finally, I would like to thank all other participants at Saxion Enschede for helping me where I needed. Without them, this thesis could not have been written.

While writing this thesis, I made use of several software applications to help me structure data and generate ideas. I have used Amberscript for the transcription and Atlas.ti for the coding of all the analyzed data. Moreover, I have used ChatGPT to generate ideas during this thesis. I have not used any information or text provided by ChatGPT to claim as my own. I take full responsibility for all the information in this whole thesis.

I hope that you will enjoy reading my thesis.

Jeroen Scheffer

Enschede, Januari 2024

## *Definitions:

**Innovation platform:** A systematic and adaptable innovation guide, incorporating methodologies, principles, and tools, which support an innovation process, providing a systematic approach for innovation from ideation to implementation.

**TIP:** Technology Innovation Processes. The term "TIP" is used within Saxion Enschede. It is an innovation platform that exists of an innovation paradigm, framework, methods, and tools that acts as a guide for innovating in a systematic manner. In this study, TIP is the innovation platform that is analyzed. A more detailed description of TIP can be found in *"3.4.1 Case study".*

**Maturity model: "**Maturity models describe and determine the state of perfection or completeness (maturity) of certain capabilities. The application of this concept is not limited to any domain. The progress in maturity can either be seen as defined evolution path (life cycle perspective) or potential for desired improvements (potential performance perspective). Therefore, maturity models define simplified maturity stages or levels which measure the completeness of the analyzed objects via different sets of (multi-dimensional) criteria" (Wendler, 2012).

**Maturity Grid:** A maturity grid is a visual representation that assesses the maturity of individual components of a process, a system or, in this study, an innovation platform. Maturity grids can be used both as assessment tools and as improvement tools (Maier et al., 2009).

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# 1. Introduction

Executing innovation systematically is often challenging, certainly for novices who may lack knowledge, skills, and experience (Bucherer et al., 2012). These novices are defined as beginners who have little to no experience with the situation in which they are expected to perform tasks (Benner, 1982). In this context, these tasks are with regard to innovating. To address this challenge for novices, Saxion Enschede, a higher education institution in the Netherlands, started with designing an innovation platform* that helps to innovate in a systematic manner. This platform consists of an innovation paradigm, a framework, methods, and tools. This platform is called Technology Innovation Processes (TIP*). The platform provides a structured method for innovating systematically. TIP was then implemented within a minor course that Saxion offers, where novices learn to innovate systematically with the help of TIP. Feedback is gathered by the developers of TIP and is provided by teachers and students from Saxion, and clients who are involved in the minor course by providing innovation problems. This feedback loop is done annually, after which TIP is improved iteratively. However, little research or analyses were done to understand the current maturity level of TIP and its ability in guiding innovating systematically. With knowledge on the maturity of TIP, it can be improved accurately, which helps with its goal: improving students' innovation outcomes.

This can be tested with a maturity model that is tailored to the specific needs of the assessment of innovation platforms (Wendler, 2012b). In a systematic mapping study on maturity models, Wendler, (2012) summarized multiple definitions of a maturity model as following: "*Maturity models describe and determine the state of perfection or completeness (maturity) of certain capabilities. The application of this concept is not limited to any domain. The progress in maturity can either be seen as defined evolution path (life cycle perspective) or potential for desired improvements (potential performance perspective). Therefore, maturity models define simplified maturity stages or levels which measure the completeness of the analyzed objects via different sets of (multi-dimensional) criteria."* Following this definition, a maturity model can analyze the completeness and effectiveness of an innovation platform. In this case, a maturity model provides a structured manner to evaluate the effectiveness and completeness of TIP. A maturity model is not limited to one specific field or domain. For each domain, a maturity model can be tailored to meet its specific needs. This is why a maturity model can be tailored for assessing the completeness and effectivity of an

innovation platform. A maturity model typically exists of a set of maturity levels through which an entity progresses. In this case, this is the process of the development and the effectiveness of TIP.

To the knowledge of the researcher, no model exists to assess the maturity level of innovation platforms. Without this model, it is challenging to gain knowledge on current state of perfection or completeness of an innovation platform. This research aims to address this gap by developing an assessment model that evaluates the maturity level of innovation platforms, oriented to guide decision makers with enhancing their platform. This tool will then be applied to TIP as a case study, which will provide insights to its current maturity. The tool will include multiple dimensions that are important for the evaluation of maturity levels of an innovation framework. The study will focus on the development of the maturity assessment criteria and its application to TIP, resulting in two research questions.

Assessment of Platform Maturity: *How can the maturity of an innovation platform be measured?*

Maturity Level of TIP: *What is the current maturity of the individual components of TIP, following the maturity model?*

This research intends to contribute to the literature by developing a maturity model for measuring maturity levels of an innovation platform. Furthermore, by providing insights in specific aspects of an innovation platform, the tool enables developers to focus on the aspects that require improvement and improve the maturity of their innovation platform. Besides that, the research tries to close a knowledge gap that has not been studied yet; the maturity assessment of innovation platforms. Therefore, this research contributes by expanding knowledge on innovation platforms. In summary, bridging this knowledge gap will result in improved innovation processes, guided-decision making, enabling continuous improvement of innovation platforms, and expanding the knowledge in the field of innovation management.

The intended contributions to practice are improvements in informed decision making. By having more targeted information, developers can make more informed decisions on the development, implementation, and use of a platform. Also, by providing an assessment of the maturity level of innovation platforms, organizations can make evidence-based decisions, which improves their ability of executing innovation practices. Lastly, targeted improvement of innovation platforms can potentially improve the performance regarding innovating of its users, given that users apply the platform as it is intended. It is essential to identity that only

the improvements of a platform will not guarantee improved utilization. To guarantee this, a holistic approach should be used, where it is recognized that the effectiveness of a platform is directly tied to both its foundation and its application. To enhance the effectivity of a platform, its enhancement should simultaneously focus on theoretical optimization, as well as optimal utilization and application of the platform.

In the case of this thesis, the innovation platform that is analyzed is TIP. It is an innovation platform that exists of an innovation paradigm, framework, methods, and tools that acts as a guide for innovating in a systematic manner. In this study, TIP is the innovation platform that is analyzed. A more detailed description of TIP can be found in *"3.4.1 Case study"*.

# 2. Theoretical framework

The following theoretical framework acts as a foundation for this study. First, key theoretical concepts will be examined, followed by previous relevant literature. These theoretical underpinnings will form the basis to analyze the maturity of innovation platforms and will grant a deeper understanding of the theory.

## *2.1 Key theoretical concepts*

Innovation is an increasingly important factor for business performance, which is why innovation management is an increasingly covered topic in the literature (Fontana & Musa, 2017). Innovation management is often described as an organization's capability to renew itself to create and enhance value for their stakeholders. This is done by managing the business discipline that aims to guide for a systematic, repeatable, and sustainable innovation process (O'Sullivan & Dooley, 2009). The management of innovation sets the basis for successful innovation practices in organizations (Oke, 2007).

A development process that incorporates design science, follows an iterative design process, which refers to a cyclical process of designing, testing and measuring, and redesigning, repeated as often as necessary (Ledgard et al., 1985). Through annual feedback received from stakeholders in the form of surveys and interviews, a platform is redesigned and improved. This iterative development enables a flexible and responsive design (Anderson et al., 2018). Through the annual feedback, designers stay engaged with the method, which also contributes to the continuous learning process of the designers (Kelley et al., 1984).

The stages in the iterative development of innovation platform can be assessed and measured on maturity levels. Becker et al. (2009) described a maturity level as a staged roadmap for assessing the capabilities of an organization with respect to a specific management domain. At each level, specific characteristics and goals are defined, with higher levels indicating that the characteristics are more advanced and the scores are higher. When the defined goals of a maturity level are met, the characteristics of an organization (on paper) 'advance' to the next and higher level of maturity, which is again defined by new, more advanced goals. The interplay between maturity and iterative development was also underpinned in the research of Jia et al. (2011), where the concern arises about the connection between a maturity model and the concept of continuous improvement. Maturity models define a set of maturity levels or stages, which describes the development of processes (Klimko, 2001). However maturity models are mainly existing for process improvement, its principles can be applied more broadly to guide the development of other products (Pöppelbuß & Röglinger, 2011). Hence, it can also be applied to the development of an innovation platform . For practical application, maturity models are expected to disclose current and desired maturity levels and to include respective improvement measures (Pöppelbuß & Röglinger, 2011). Moreover, the intention is to diagnose and eliminate deficient capabilities. Rummler & Brache (2013) refer to such tools as engines for roadmaps for guiding organizations. The basic principles are describing stages and maturation paths. Characteristics for each stage are described and a logical relationship exists between all stages. This is what makes a maturity model also suitable for the development process of an innovation platform. The stages of a maturity model are sequential and hierarchical. Lastly, the levels of maturity in a maturity model should be closely connected to the specific process that is assessed with the maturity model, in order to ensure that the maturity model is tailored to the characteristics and progress of the specific process that is evaluated. (Gottschalk & Sollisther, 2009).

## *2.2 Previous studies*

In the last few decades, there has been a rising interest in maturity model research. Much research was aimed to develop a conceptual model. Other research was driven by the usage of the models, validation, and mapping of the existing maturity models (Wendler, 2012b).

In a systematic mapping study on the maturity of maturity model research, it was found that maturity models are applicable generally (Wendler, 2012b). This is the first of two systematic reviews of the existing maturity model research to date (García-Mireles et al., 2012; Wendler, 2012b). Here, researchers were called out to study existing maturity models before designing

one, while looking out for the suitability of other existing maturity models. Moreover, the validity of developed conceptual maturity models should be checked, as this is usually not done (Wendler, 2012b). Namely, most published maturity models are based on practices and success factors, but lack a theoretical basis and methodology (García-Mireles et al., 2012). Moreover, little is known on how to develop maturity models based on theory and methodology. For example, Wendler (2012) described that out of the observed studies that dealt with the construction of maturity models, 48 were based on a design-orientated approach and the other 69 articles were based on a pure conceptual approach. Moreover, without any validation or application, the suitability and usefulness are doubtful (Hevner et al., 2004).

Several types of maturity models exist. Each type of model has a different purpose or was made for a different industry. The concept of measuring maturity was introduced at the Carnegie Mellon University in 1987 (Humphrey, 1987). Four years later, the Capability Maturity Model (CMM) was created at the Carnegie Mellon University. This model was later renewed into the Capability Maturity Model Integration (CMMI) and is broadly validated, altered for different industries, and used all over the world (Bruin et al., 2005). Other maturity models are the Business Process Maturity Model (BPMM), and the Project Management Maturity Model (PMMM) (Demir & Kocaba, 2010; Tarhan et al., 2016). Despite the high number of maturity models that are created based on the ones above, the use and validation of these new models are minimal (Tarhan et al., 2016). However, CMM, BPMM, and PMMM are highly validated in research.

When developing new maturity models, it is not sufficient to build them in terms of content and structure (Wendler, 2012b). Contradictory, to ensure the applicability and benefits of the maturity model, it must be tested by, for example, real life application. The results of this test can then be used for further improvements of the maturity model. Design-oriented research is therefore often used for the development of maturity models (Wendler, 2012b). One of the most cited frameworks on design principles is the *Design Science Research Framework* by (Hevner et al., 2004), which is based on the work of March & Smith (1995). This framework consists of seven guidelines that serve as a basis for developing models. An overview of the guidelines can be seen in table 1. All these guidelines should be addressed when developing new maturity models, to ensure their applicability and benefits (Wendler, 2012b). Other researchers also developed maturity models in highly cited articles, based on these guidelines (Becker et al., 2009; Hong et al., 2014). Wendler (2012) highlights the importance of

guidelines 3 and 5, which state that maturity models should be rigorously evaluated, to ensure its validation.

The evaluation methods for design research were broadly described in the research of Hevner et al. (2004). One of the evaluation methods that was described is an observational case study, where maturity models are studied within a business environment. The applicability of the maturity model can be demonstrated via well-selected evaluation methods (Kleindorfer et al., 1998; Zelkowitz & Wallace, 1998). Lastly, the importance of rigor application of methods for construction and evaluation is highlighted (Hevner et al., 2004; Wendler, 2012b). The rigorousness is often assessed by appropriate data collection and analysis techniques. Deriving rigorousness must be limited to the use of theoretical foundations and research methodologies (A. Lee, 1999).

Table 1: Design Science Research Guidelines (Hevner et al., 2004; March & Smith, 1995)

| Nr. | Guideline | Description |
|---|---|---|
| 1 | Design as an artifact | Design-science research must produce a viable artifact in the form of a construct, a model, a method, or an instantiation |
| 2 | Problem relevance | The objective of design-science research is to develop technology-based solutions to important and relevant business problems |
| 3 | Design evaluation | The utility, quality, and efficacy of a design artifact must be rigorously demonstrated via well-executed evaluation methods |
| 4 | Research contributions | Effective design-science research must provide clear and verifiable contributions in the areas of the design artifact, design foundations, and/or design methodologies |
| 5 | Research rigor | Design-science research relies upon the application of rigorous methods in both the construction and evaluation of the design artifact |
| 6 | Design as a search process | The search for an effective artifact requires utilizing available means to reach desired ends while satisfying laws in the problem environment |
| 7 | Communication of research | Design-science research must be presented effectively both to technology-oriented as well as management-oriented audiences |

García-Mireles et al. (2012), performed a systematic literature review on the development of maturity models. Firstly, they describe the different categories of maturity levels. Moreover, the purpose of the maturity model defines if the model is descriptive, prescriptive of

comparative. For a descriptive model, the outcomes describe the current situation without information to improve capability. Prescriptive models enable paths for improvement, including an assessment of the current situation. Lastly, a comparative model benchmarks similar practices among organizations (De Bruin et al., 2005).

A few conceptual methods for developing maturity models have been proposed in recent years. For instance, De Bruin et al. (2005) developed a framework for the development of maturity models in different application domains. Becker et al. (2009) proposes a design method based on design science guidelines. Van Steenbergen et al. (2010) designed a method for the development of maturity models with a focus on one specific area. This area is dependent on the focus of the maturity model. (Maier et al., 2009) presented a structured approach to creating a maturity matrix which analyzes multiple components of one whole process, while Mettler & Rohner, (2009) dive into the benefits of a situational maturity model, to filter out the static view of organizations and maturity models. Lastly, the proposal of Von Wangenheim et al. (2010) is based on knowledge management theory. These proposed methods have formed the foundation of maturity model development within research for the last decade (García-Mireles et al., 2012).

Conclusively, this study focuses on the development of a prescriptive maturity model for the assessment of innovation platforms, as the focus is on enhancement. As the context of the innovation guide revolves around the guidance of novices, the focus of this maturity model is on guiding and educating innovation. As the development of a model is a part of design science, the design science principles of Hevner et al. (2004) are used. In addition, the most suitable maturity model for this subject is CMMI, -widely recognized in both practice and research. It has been applied to software development, project management, and more. Its principles, like the focus on the process of the development, make it suitable for the analysis of the development of an innovation platform. Hence, it is flexible, which makes it possible to tailor it for other domains. Therefore, the maturity model that is developed in this research is based on the principles of CMMI. Lastly, the method for developing a maturity model is determined. The guide of Maier et al. (2009) provides a methodology for developing a maturity model that focuses on individual components, which enables the assessment of individual aspects of an innovation platform. This model with individual aspects is called a maturity grid. This approach ensures a systematic assessment, leading to meaningful insights into innovation platforms.

### *2.3 Conceptual maturity model*

Following the methodology, the maturity model follows the principles of CMMI. Therefore, the labels that are given to each level of maturity are adopted. Also, the behavioral characteristics are described. The behavioral characteristics follow an evolutionary path from an initial effort of creating an innovation platform to an established platform that is constantly refined through feedback. This conceptual maturity model can be seen in table 2. Additionally, the underlying assessment components of an innovation platform need to be assessed to provide a complete overview of the maturity. Therefore, the focus lies on the process of the development and the maturity of the assessment components.

Table 2: Conceptual maturity model with in- and outputs

| *Maturity Level (Score)* | *Inputs* | *Expected Outcomes* | *Behavioral characteristics (description)* |
|---|---|---|---|
| Initial (1) | - Basic knowledge of the subject matter. | - Defined basic lesson structures and objectives.<br>- Increased awareness of structured teaching.<br>- Beginning knowledge and experience with innovating. | At this level, the teaching approach to innovation for novices is in its early stages. Lessons are simple and lack structure. The focus is on introducing novices to the innovating and creating initial interest in innovation. |
| Managed (2) | - Defined curriculum objectives.<br>- Basic teaching resources and materials.<br>- Identified exercises and practical applications related to lessons. | - Lessons aligned with curriculum objectives.<br>- Integration of exercises and practical applications.<br>- Improved novices' engagement and understanding through practical experiences. | In this level, there's a more organized approach to teaching innovation. Curriculum objectives are defined, and lessons are aligned accordingly. Basic exercises and practices related to the lessons are integrated to enhance novices' understanding and engagement. |
| Defined (3) | - Structured assessment methods.<br>- Expanded curriculum with learning outcomes.<br>- Diverse teaching approaches tailored for novices. | - Structured assessment results providing insights into novices' understanding.<br>- Improved methods for teaching innovation concepts. - Evident | At this stage, the teaching method is well-defined and structured. Assessment methods are established, and the curriculum is enriched with specific learning outcomes. Diverse teaching approaches are tailored to suit |

| | | | |
|---|---|---|---|
| | | adaptability to novices' learning styles. | novices' needs, optimizing the learning experience. |
| Quantitatively Managed (4) | - Performance metrics and data collection tools.<br>- Continuous assessment results and feedback.<br>- Data analysis tools and techniques. | - Clear performance metrics demonstrating teaching effectiveness.<br>- Data-driven decisions for further improvement.<br>- Enhanced feedback mechanisms to optimize the teaching process. | In this level, a quantitative approach is taken to manage the teaching process. Performance metrics and data collection tools are utilized to measure teaching effectiveness. Data-driven decisions are made based on the analysis of continuous assessment results and feedback, ensuring ongoing improvements. |
| Optimizing (5) | - A culture of continuous improvement and innovation.<br>- Insights from data analysis and performance evaluations.<br>- A supportive teaching environment encouraging experimentation. | - Innovative teaching methodologies continually refined and implemented.<br>- Consistent enhancement of teaching practices based on insights and feedback.<br>- A culture of ongoing improvement and innovation in teaching. | At the highest level of maturity, teaching innovation is a well-optimized and innovative process. There's a culture of continuous improvement and experimentation. Insights from data analysis and performance evaluations are used to refine and enhance teaching methodologies, fostering a culture of ongoing improvement and innovation in teaching. |

### *2.4 Assessment components*

As the context of the innovation guide revolves around the guidance of novices in learning a certain skill, the focus of the maturity grid is on the ability of an innovation platform in educating and guiding an innovating process. Most identified components that were used for the maturity grid are based on research of Tran et al. (2017), where assessment components for teaching creativity were developed. These components were all based on teaching and learning a certain skill. Therefore, the components can also be applied to teaching about developing innovation skills. The assessment components that are used in this research are: (1) individual innovation competencies, (2) knowledge, skills and attitudes of a subject and

cross-disciplinary subjects, (3) teaching and assessment methods and tools, (4) teaching modes, (5) teaching and learning environment, and (6) student-centric learning environment.

The first component is about students' innovation competencies, which include creative thinking skills, social skills, project management skills, future orientation, and personal characteristics (Hero et al., 2017). The second component is knowledge and skills of a specific subject and cross-disciplinary subjects. These include the social and technical skills. Technical skills are the know-what and know-how and the specialist skills in the field (Hoidn & Kärkkäinen, 2014; C. Lee & Benza, 2015). These are both in terms of knowledge and methods. The third component requires teachers to focus students on real-life situations. Moreover, it requires an appropriate use of a range of teaching methods, use of ICT, and using the existing knowledge of students (Tran et al., 2017). The assessment methods are important for this component as well. Teachers must properly assess the student innovation competencies. The fourth component focuses on the opportunity for students individually of in groups. This enables students to optimize multiple perspectives (Tran et al., 2017). The fifth component requires teachers to optimize the learning environments, which contributes to the efficiency of education (Gislason, 2010). The sixth component revolves around student-centric learning environment. This refers to the teachers' flexibility in attending to students' needs to complete activities, time-management rules and procedures and the students' responsibility for management (Marzano, 2003a). Also, the quality of learning material is an important factor for the student-centric learning environment.

Other components that are important for the quality of the education of innovation is 7) the complexity of the lessons (Kuhn, 2008). Instead of taking effort in simplifying complexity, it is important to accept that real-life situations are multi-dimensional, non-linear, interconnected, and unpredictable (Kuhn, 2008). If the task complexity becomes too high, students lose confidence in performing well. In addition, students that have high confidence towards a complex task, outperform students with a lower confidence (Zhou et al., 2022). Moreover, 8) a solid theoretical foundation is crucial for the development of an innovation platform (Addessi, 2020). It provides a basis for understanding and for analyzing the platform. It also validates the platform by building on existing knowledge. Lastly, 9) quality management is an important component for making improvements of processes (Walsh et al., 2002). Gathered feedback on the platform needs to be analyzed and used for iterative, effective improvements of the platform. An overview of all assessment components and assessment criteria can be found in table 3.

Table 3: Components, descriptions and sub-components for assessment of innovation platforms.

| | **Description and Sub-components** |
|---|---|
| 1. Innovation Competencies | 1.1 Innovative thinking skills: Creativity - Critical thinking - Bravery of students |
| | 1.2 Development of student curiosity: Students ask questions - Teachers ask questions |
| | 1.3 Students' innovative products: Creative answers - Innovative ideas - Innovative/new perspectives |
| | 1.4 Positive attitude towards innovation |
| 2. Knowledge and Skills | 2.1 Technical skills: Understanding of subject knowledge - Understanding of cross-disciplinary subject knowledge |
| | 2.2 Social skills: Communication - (Cross-cultural) collaboration – Teamwork – Leadership - Students' awareness of impact of appropriate behavior - Presentation skills |
| 3. Teaching and Assessment Methods | 3.1 Teaching based on real-life situations |
| | 3.2 The use of an appropriate range of innovative teaching methods |
| | 3.3 The use of students' existing knowledge and experience |
| | 3.4 Multiple assessments of students' innovation competencies |
| 4. Modes of Teaching | 4.1 The opportunity for students to work both in groups and individually |
| 5. Learning Environment | 5.1 Development of a positive relationship between teacher and student |
| | 5.2 Classroom atmosphere: Positive – stimulating - friendly |
| 6. Student-centric learning environment | 6.1 Observing and meeting the student learning needs and existing knowledge |
| | 6.2 Enough time for students to fulfill tasks |
| | 6.3 Guidance in time-management |
| | 6.4 Learning material quality |
| 7. Complexity | 7.1 Using real-life – complex - and unpredictable cases |
| | 7.2 Use an optimal balance between complexity and students' skills: Improvement of self-efficacy - Students' confidence towards the task complexity |
| | 7.3 Maintain a challenging task: Students engagement - Students interest |
| 8. Theoretical Foundation | 8.1 Empirical support |
| | 8.2 Relevance and applicability: The alignment of all theory with the goals and needs of the paradigm |
| | 8.3 Flexibility/Adaptability |
| | 8.4 Accessibility |
| 9. Quality Management | 9.1 Feedback analysis |
| | 9.2 Improvements based on feedback |

| | |
|---|---|
| | 9.3 Flexibility/adaptability |
| | 9.4 Points of improvement |

# 3. Methodology

This research used a design-oriented research approach, which included a review of the literature and iterative design. After the initial design principals were dealt with, the focus shifted from theoretical foundation to the creation of the maturity model. The methodology of creating a maturity model was based on the practitioner guide from Maier et al. (2009). This guide consists of 4 phases: *planning, development, evaluation, and maintenance*. Maintenance is the only phase that occurs after this research, which was therefore excluded from this research. It should be noted that it remains important to continue with this phase after the evaluation phase.

## *3.1 Planning*

The audience for this maturity model were all developers of the innovation platform. These were the stakeholders that were most closely related to the innovation platform. These were also the ones who implement improvements and are the quality managers of the platform. The aim was to identify what improvements were needed and whether a previous improvement initiative has been successful. The scope of the maturity model was focused. It was designed for innovation platforms. Succes criteria for this maturity model were usability of and usefulness for the stakeholders.

## *3.2 Development*

The content of innovation platforms mainly exists for knowledge transfer, developing innovation strategies, and providing structure to the innovation process.

### *3.2.1. Conceptual maturity model*

After establishing the main content that needed to be assessed, maturity levels were formulated. For this, multiple existing and widely validated maturity models were analyzed. The principles of CMMI were taken and tailored to the specific needs of assessing an innovation platform, due to its flexibility to be adapted for other scientific fields. A prescriptive maturity model was created, to enable paths for improvement, including the assessment of the current situation (García-Mireles et al., 2012). Next, the maturity levels were determined. For this, the maturity levels of CMMI were adopted.

According to Maier et al. (2009), the focus of the outcomes of the maturity model can be on the process or on end results. If the focus is on the process, the goal is to identify points of improvement through a discussion. The method for scoring is then qualitative of nature (Maier et al., 2009). If the focus is on end results, one score is given for an overall assessment of the capability and overall maturity level of the project and the scoring method is often quantitative (Maier et al., 2009). By focusing on end results, the mean score of all components is taken. By doing this, higher scores could be masked by lower scores and vice versa (Maier et al., 2009). Also, differences in individual scores of components cannot be seen. For this research, the focus laid on the identification of points of improvement. Therefore, the focus of the maturity model laid on the process of the development of innovation platforms.

#### *3.2.2. Components of innovating skills*

Through literature research on assessment criteria of innovation skills, components of an innovation platform were revealed. The findings of these sources were summarized to establish a theoretical foundation for the assessment components.

For the formulation of cell texts, the intersection between the process area and the maturity levels, the behavioral characteristics for each maturity level of each component were described. The definition of these cell texts depended on how the components can be incrementally developed in an evolutionary way (Maier et al., 2009). Per component, the evolutionary path of maturity was defined. This can be found in appendix A.

#### *3.2.3. Maturity grid development*

For the development of the maturity grid, all maturity levels, components, sub-components were merged in one comprehensive document. Because the focus of the maturity model was on the process of the development of an innovation platform, the focus laid on the individual scores of the components identified in table 3. Therefore, the maturity levels that were established are tailored to the individual components of table 3. This enabled individual scoring for the focus of identifying points of improvement (Maier et al., 2009). An overview of this can be found in appendix A. With the identified maturity levels, the components and the maturity grids for every component, a scoring list was created. This scoring list can be found in appendix B.

The sub-components were scored using a 5-point Likert scale that assesses the quality of the sub-components, from ‘poor’ to ‘excellent’. Components were scored by calculating the weighted score of all sub-components that are tied to the component. This score represents the

maturity level that describes the component stage. The given scores can be subjective. To reduce this bias, multiple persons should perform the scoring.

In order to select the users of the maturity grid to select improvement measures, prescriptive maturity models should include a decision calculus (Pöppelbuß & Röglinger, 2011). This helps decision makers to evaluate defferent alternatives with respect to given objectives and to identify which alternative satisfies the objectives best (Pöppelbuß & Röglinger, 2011). This was done with the help of the 'Analytical Hierarchy Method' of (Saaty, 1980) This is a mathematical method which uses priorities of stakeholders to determine the relative importance of all components and sub-components. Every component is compared with each other. In this process, a score of 1 to 9 is given to visualize the relative importance of the two compared components. After every component and sub-component was compared with each other, weights were calculated for each component. These weights lie between 0 and 1, indicating their relative importance. Every component is compared to each other to determine the overall maturity of the innovation platform. Moreover, the sub-components are compared with each other to determine the overall maturity of the components. In addition, a consistency index is calculated to ensure that the weights are consistent and valid. A consistency index of <10% (0,1) indicates that the weights are objective. The weights of all sub-components are multiplied by their maturity level scores, and then added up to calculate the overall weighted average maturity for all individual components. Then, all the weighted average maturity scores of the components are multiplied with their weight, resulting in the overall maturity of the innovation platform. These scores are shown with two decimal places, to show the differences between the individual components. These differences can be very minimal with two decimal places, which also means that the maturity of these (sub-) components can be minimal.

For this research, the priorities of the developer with the most overview of the platform and its utilization are used. Since this is the only developer who possesses knowledge on all these aspects, only this developer is asked to use the method. An overview of the outcomes of this method can be found in Appendix C.

## *3.4 Evaluation*

After the design phase, the validation and evaluation phase took place. During the evaluation phase, difficulties or limitations of the maturity model may be exposed (Moultrie et al., 2007). Evaluation was done through an observational single case study, which is an evaluation

method for the validation of tools (García-Mireles et al., 2012; Hevner et al., 2004; Wendler, 2012b). The choice for a case study lied within its capability to gain concrete, in-depth knowledge about a real-world subject. As the maturity model is used and feedback is gained, the model should be iteratively improved (Maier et al., 2009). The rationale behind this comes from possible new knowledge in the time after the development of the maturity model. This means that an innovation platform that currently has a maturity level of 5, could have a lower maturity level in the future. Also, to keep the model relevant and up-to-date, Moreover, the initial identified components were deductive, as these were derived from the literature review. During the evaluation phase and the case studies, inductive components could be discovered. These inductive components were then added to the maturity grid. After a couple rounds of improvement, saturation will be reached. After this point, the maintenance phase starts.

### *3.4.1 Case study*

The subject of the case study was TIP. Data was collected from Saxion Enschede, which uses TIP. Information about its design, practices, and outcomes was gathered, which was then aligned with the established maturity components and sub-components, to create an understanding of TIP's current maturity. After the maturity assessment, the strengths and weaknesses of the platform were identified. This was done by performing a close analysis of the specific goals of the maturity level that the components of TIP were operating in. By looking at these maturity levels, specific areas of improvement were identified. Overall, an assessment of the current maturity of all specific areas of TIP was visualized, which will help the designers of TIP to improve upon specific points.

In an annual minor that is offered by Saxion Enschede, novices learn how to innovate in a systematic manner by using TIP. The innovation capabilities of novices are first developed by learning theory on product ideation, problem-solving, creativity, and product development. After the theory, the knowledge is brought to practice, where the novices apply their knowledge in a real-life business case. Here, TIP acts as a toolbox and equips the novices with innovation practices, which supports them in solving complex challenges.

TIP is a platform that exists of an innovation paradigm, framework, methods, and tools that acts as a guide for novices to innovate in a systematic manner. The innovation paradigm that is used with TIP is based on the core beliefs, approaches, literature, and philosophies that guide the innovation process.

TIP operates based on structured principles and starting points. Firstly, TIP divides an innovation process in multiple smaller aspects, in order to grant an easier overview of the innovation situation. The smaller parts of the innovation process are divided by four readiness level domains and stages and gates, following the stage/gate model of Cooper (1990). The readiness level domains that are used are based on the most important roles that are needed during an innovation process. These domains are Business Readiness Level (BRL), Technology Readiness Level (TRL), Demand Readiness Level (DRL), and Manufacturing Readiness Level (MRL). TIP can only be used for technologies that have already been validated and that have a TRL 5.

The framework that is used for TIP provides structured guidelines, starting points, and best practices for teaching and learning innovation skills. This framework is called the TIP matrix. In addition to the TIP matrix, two other tools are used for TIP; a Readiness Level Assessment (RLA) tool and the Innovators Canvas. The RLA exists of a list of questions for every level of readiness of the four domains that have to be answered with yes or no. If all questions of a certain level can be answered with 'yes', the product complies with the description of the next readiness level. The Innovators Canvas is a tool for teams to develop product designs and business models. The TIP framework also displays the key components and stages of an innovation process. The methods of TIP are the approaches that are used during the minor. These approaches include interactive learning, project-based learning, problem-solving approaches, and design thinking. The tools that are used with TIP refer to all resources, innovation tools, and materials that are used to help with teaching and learning innovating.

In summary, TIP operates as a platform for guidance, is structured by a framework that uses specific methods to aid with the innovation process, and offers a variation of tools and methods to facilitate the innovation process step by step.

### *3.4.2 Data collection*

In this case, it was chosen to collect data in a qualitative manner. This is supported by the research of Seawright & Gerring (2008), who state that qualitative data collection is mostly used for cases that require in-depth analysis. This is the case for TIP, as a platform based on innovation is complex. Moreover, qualitative data is detailed, which helps providing a holistic view of TIP and its utilization.

Primary data was collected through semi-structured interviews with developers of TIP. With this method, in-depth information on the components and the decision-making processes of

the development of TIP was gathered. The whole study population was Dutch. To ensure that participants are most comfortable and able to say what they wanted, the interviews were conducted in Dutch. Also, semi-structured interviews that were already conducted by a developer with teachers and clients were used. The clients are in this case the spokespersons of the companies where TIP was used by the students of the minor.

For the interviews, a semi-structured scheme was developed. The topics were based on the components of the maturity grid of innovation platforms. Sampling was done through purposive sampling. By using purposive sampling, only participants who can provide in-depth information were selected. The targeted population of respondents for the interviews were the developers of TIP. This population consisted of three people. The target was to interview all three developers, which was achieved. The developers of TIP have the most in-depth knowledge on the development, management, and application of TIP. Therefore, semi-structured interviews were most suited to achieve all in-depth information about these topics.

Before the interviews took place, all participants needed to sign an informed consent form for research with human participants, which is developed and used within the University of Twente. After the signing, the interviews were recorded. Moreover, all data was anonymized by replacing all identifiable information with codes. These codes existed of a letter and a number, which acted to remain insights in the characteristics of participants. Developers of TIP were indicated with the character ‘D’, teachers within the minor where TIP is taught to students were indicated with the character ‘T’, and clients, whose assignments were solved during this minor by using TIP, were indicated with the character ‘C’. The indicated numbers were randomized to further ensure anonymity. To further ensure anonymity, all collected data was stored on the database of the University of Twente. All raw data that was not anonymized, was deleted after the completion of the research.

For the collection of secondary data, the study focused on qualitative data in the form of secondary sources. Relevant documents regarding TIP in the form of project reports, readers, plans, feedback data from stakeholders, and any other relevant documentary were collected. Moreover, existing feedback interviews and surveys were collected for analysis. Lastly, feedback from experts was gathered and used for constant improvement of the maturity model.

### *3.4.3 Data analysis*

This was a single case study. Data was analyzed using the framework of Morse (1994), which is a prominent analysis method for data of single case studies. This framework builds around four stages: comprehending, synthesizing, theorizing, and re-contextualizing (Morse, 1994). For the appliance of this framework, the proposed strategies of Miles et al. (2014) were used. These strategies include broad coding, pattern coding, memoing, testing summary statements, and developing propositions (Miles et al., 2014). These analytical strategies have been highly influential in case study research (Casey & Houghton, 2010; Yin, 2018). This approach to the data analysis for the case study helped with providing logic behind the data and is a rigorous method for the data analysis. All four stages of analysis strategies were done iteratively, to enable the refinement of the coding process.

At the first stage, the collected data was transcribed with the help of Amberscript, a transcription software. The transcription of the interview was done in Dutch, as translation of qualitative data is practically always bound to some sort of subjectiveness (Temple & Young, 2004). Supporting quotations were translated to English. With translating, multiple risks for bias exist (Temple & Young, 2004). To reduce this bias, translating software of Google was used and checked to filter out the researcher's own construction of meaning. Then, all data were organized in Atlas.ti, a coding software that helps organizing qualitative data into codes. First, broad coding was applied. This method started while collecting data and aided the researcher to generate complete, detailed, and coherent description of the data (Morse, 1994). Generated data were read, coded in broad, descriptive codes, and linked to the research questions. Next, the codes were organized between the components and sub-components of TIP.

The next step was synthesizing. This is merging the codes from the components to describe typical, composite patterns along the codes (Morse, 1994). This practice is also called pattern coding, or memoing (Miles et al., 2014). Here, the focus lied on recurring patterns between the codes, to reveal connections between different components. Memos were created that summarize the identified pattern for each dimension.

Relationships between different components were identified and organized. When all important data was organized within all components, the data was tested with the maturity grid that was constructed for the maturity of each component of an innovation platform. First, the alignment between the maturity grid and the data was examined. This was done for every component. For this, a score is assigned to each sub-component of TIP. Subsequently, the

scores of the sub-components were multiplied by the weight that belongs to a certain sub-component. The outcome of this calculation presented the current maturity level of the components of TIP.

Lastly, the results were used to transfer the study findings towards practice. The AHP method was done with the help of one developer, to map the priorities of the developers of TIP. With the assessed maturity levels, it became clear where the strengths and weaknesses of TIP laid. Summary statements for each component were created, which also describe the links between components, to enable a more streamlined implementation of possible improvements. These summaries and maturity levels of the dimensions form the foundation of the conclusion of the case study.

### *3.5 Phase 4: Maintenance (after the thesis)*

The maturity model will be implemented at Saxion Enschede, to iteratively improve their innovation platform. With a systematic approach and clear instructions on how to use the maturity model, the organization is guided to use the tool correctly and assess their own platform. During the maintenance phase, the model is refined in accordance with new knowledge and research.

## 4. Results

In this section, the results of the case study regarding TIP are presented. First, the inductive results are presented. (sub-) components that were excluded from the maturity grid are described. Next, the maturity of TIP is evaluated through the maturity grid. The results are presented in a narrative manner, with supporting quotations from collected data. By doing this, context is provided to the data and insights are communicated. Next to that, the results are analyzed and compared with literature, after which a score will be given to each sub-component and components.

### *4.1 Inductive results*

After data analysis, it became clear that 10) *"the use of tools",* should be included in the maturity grid for innovation platforms. Sub-components of the use of tools are their relevance to the innovation stages, the flexibility and adaptability, the coherence between tools, their user experience, and their applicability for real-life situations (cases).

After data analysis, it has been determined by the researcher that sub-component 1.2: 'Development of student curiosity: Students ask questions - Teachers ask questions' was not applicable to the maturity assessment of TIP, because it lacked practical relevance and measurable criteria within the context of this study.

All developers of TIP share the opinion that the use of existing knowledge at the start of the minor TIP is not feasible and not practical. Students may have some knowledge on the subject, but the focus at the start of the minor TIP lies on Sub-component 3.3 was therefore excluded from the maturity grid tailored to TIP.

During the interviews, it became clear that nor developers, nor teachers can influence which classrooms are used for specific lessons. Due to the lack of practical relevance, it has been determined by the researcher that sub-components 5.3 and 5.4 were excluded from the maturity grid.

During the initial phase of the case study, it became clear that the use of supporting tools was an important factor for the assessment of TIP. Therefore, the component 'Tools" was added to the maturity grid, to ensure a complete assessment of TIP.

All these inductive results were used to refine the maturity grid. The complete maturity grid can be found in Appendix B.

## *4.2 Thematic analysis*

### *4.2.1 Component 1: Innovation competencies*

Students learn to use and enhance their creative thinking while using TIP. This can be seen in the outcomes of the students' reports, and this indicated within the interviews with teachers and developers. One developer indicated that students learn to think creatively, while also managing their time to create innovative products. One of the teachers indicated that students are naturally skilled in creating innovative perspectives due to youthfulness. However, due to a lack of experience, these perspectives are often not feasible:

Teacher 1*: "But what I say; younger people often have a lot of shutters open. Still a bit creative. However, I often find that they don't fully know what they are doing. So, they sometimes miss the mark."*

Developer 3: *"Students learn to think creatively, but in addition, to manage their project effectively so that the outcome of the innovation process is valuable."*

Next, the attitude of students towards innovating using TIP is being analyzed. In 2021, 100% of the students would use TIP again for a next innovation problem. In 2022, 24% would recommend the minor to other students and 35% of the students were indifferent and answered the question with '*maybe*'. In 2023, 89% of the students would use TIP again. One of the two students who would not use it again, said that only parts of it were necessary. Also 89% of the students would recommend the minor TIP to other students. This can be seen in Figure 1.

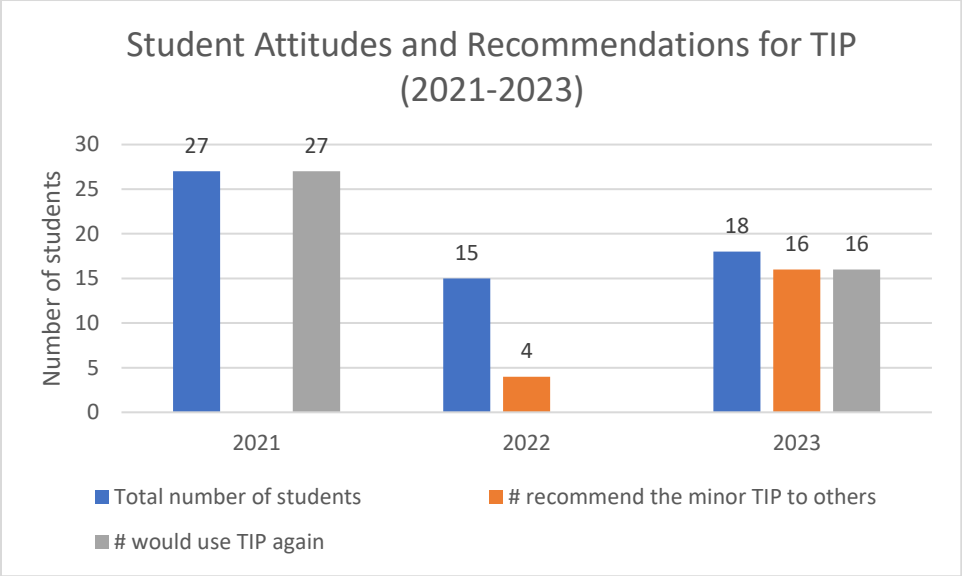
*Analysis*

TIP exhibits a moderate level of improvement of innovation competencies among its users. Also, students take a positive stand towards using TIP. This positive attitude towards using TIP and innovating fosters the ability to learn. This is supported by the research of (Chen et al., 2018), where it is proven that a positive attitude towards learning significantly impacts academic achievement. This can also be seen in the case of TIP, where nearly all students possess a positive attitude towards TIP. Over the last two years where the TIP minor was offered, an increase from 27% in 2022 to 89% of the students in 2023 who would recommend the minor TIP to other students. This indicates an increase in the positive attitude of students. The scores and the maturity level of component 1: 'Innovation competencies' are presented in Table 4.

Table 4: Weighted score Innovation competencies and scores of sub-components

| Component | Maturity level | Sub-components | Score | Weight |
|---|---|---|---|---|
| 1. Innovation Competencies | 3,11 | | | |
| | | 1.1 Innovative thinking skills: Creativity - Critical thinking - Bravery of students | 3 | 0,416 |
| | | 1.2 Development of student curiosity: Students ask questions - Teachers ask questions | 2 | 0,236 |
| | | 1.3 Students' innovative products: Creative answers - Innovative ideas - Innovative/new perspectives | 4 | 0,198 |
| | | 1.4 Positive attitude towards innovation | 4 | 0,15 |

Figure 1: Student Attitudes and Recommendations for TIP (2021-2023)




*4.2.2 Component 2: Knowledge and skills*

Users of TIP actively learn the essence of innovating. During the minor TIP, students learn innovating in three parts, out of which one is fully based on theory. The second part is about applying theory in a delineated context using a toolbox. The third part is about applying the knowledge and tools to a real-life business case.

However, 4 out of 6 teachers talked about a lack of understanding in students about the whole innovation situation. Students can use tools, but do not truly understand them. Moreover, after using tools, they cannot argue why and how they used the tool.

Teacher 1: *"They don't understand the tool, so they don't actually understand what they are doing yet. There are some of whom I see at the end: 'You have understood what the TIP model is all about.' They don't feel that, they don't see that, they don't get that feeling."*

Teacher 5: *"That they mainly see the individual tools and not so much the big picture. That in their youthful overconfidence they often think that everything will work out. That they are less aware of the context of that organization and the unruliness in that organization…"*

Two clients indicate that students lack communication skills. One client said that the students who worked on their business case contacted the client after 5 weeks after starting the assignment, did not include the client in the process of the case and the use of tools, and did not clearly understand the assignment. However, another client told that however the communication between students and client lacked severely, the outcomes of the business

case were outstanding. Also, students do not show a clear role division. Students do not always show leadership. This leads to a lack of communication as well.

Client 4: *"No, not that I know of. No, not tested in any case. I think these are very clear templates to use and I also think they could have been applied to us. Maybe they applied it, but didn't make it known."*

Client 1: *"...I was very little involved in the process and that was disappointing to me. So that, yes, because, because it is my innovation after all. I'm an entrepreneur. So I almost wasn't involved much. But I did get a really nice final report the first time."*

Client 4: *"... there was no leader who said: 'Hey, we're going to do that, and you do this, do that. There wasn't one either."*

*Analysis*

According to many teachers and clients, it is noticeable that students often lack technical skills, social skills, or both. Many teachers indicate that students do not acquire in-depth knowledge on the whole innovation situation. Knowledge on the use of tools is superficial as well. Moreover, students that work with TIP sometimes lack social skills. Clients indicated that communication between students and the clients was lacking. Therefore, expectations were not properly managed and the client did not have insights on the progression. Mirghani et al. (2014) argued that this behavior and knowledge and skills of students is due to the format of teaching. While students that are in their first two years of studying at a higher education institution are usually used to more superficial learning, students that have studied for a longer time are more likely to be sensitive for deep learning. Superficial learning mainly focuses on external goals as getting a particular grade or impressing someone. Deep learning requires active interest in the course and intrinsic motivation. Mirghani et al. (2014) found that new students often lack this motivation and are more likely to learn better from superficial learning rather than deeper learning. Also, the switch from superficial in high school and the first years of higher education towards a deeper learning approach in the later years could be the reason why the students are not highly socially skilled. Furthermore, in the study of Mirghani et al. (2014), it was found that the approach for superficial scored significantly higher among male students. Learning styles among students are not similar throughout higher education. This needs to be taken into account when developing a learning method strategy. The scores of component 2: 'Knowledge and skills' are presented in Table 5.

Table 5: Weighted score Knowledge and skills and scores of sub-components

| Component | Maturity level | Sub-components | Score | Weight |
|---|---|---|---|---|
| 2. Knowledge and Skills | 2,5 | | | |
| | | 2.1 Technical skills: Understanding of subject knowledge - Understanding of cross-disciplinary subject knowledge | 2 | 0,5 |
| | | 2.2 Social skills: Communication - (Cross-cultural) collaboration – Teamwork – Leadership - Students' awareness of impact of appropriate behavior - Presentation skills | 3 | 0,5 |

### *4.2.3 Component 3: Teaching and assessment methods and tools*

The whole minor TIP revolves around real-life business cases. From the start, students are prepared for the business case. The minor starts with teaching and assessing basic innovation knowledge, after which a balanced teaching method between a real-life case and a delineated context and pre-determined tools are used. In the last section of the minor, the real-life business case, students are more depending on their own knowledge and skills. The business cases must meet criteria that have been established to prevent unusable cases or cases that lack educational content. During the minor, students must learn knowledge, have to make several reports and have to present their findings.

Furthermore, students are assessed through multiple tests, divided over the whole minor. Students are assessed through a knowledge test, a pitch, a report, an innovation file, and a presentation and defense.

*Analysis*

Mirghani et al. (2014) also explore the influence of teaching methods on learning styles. It is noted that an optimal process of learning includes starting with lectures as the main method to transfer knowledge that is crucial for the learning process. Thereafter, the focus shifts to more deeper learning with the use of problem-based learning. This process is wielded within the minor TIP as well. The students' approach towards learning is also influenced by their experience with problem-based learning. (Newble & Gordon, 1985) reported that students in all years scored high on a superficial approach, but first- and second-year students scored lower on a deep approach. By using problem-based learning, a deep approach towards learning is increased (Tiwari et al., 2006). According to (Groves, 2005), workload is of significant

influence on the willingness of student to take a superficial or deeper approach towards learning. Given that the workload was at a perfect level in 2023 according to nearly all students, indicates that this is well laid out by the development of the minor TIP. This perfect level was the highest score on a 5-point Likert scale from 'very poor' to 'perfect'. Assessment based on both individual and group work is an effective manner to assess students (Pereira et al., 2016). Within the minor TIP, this is executed by including multiple individual assessments, next to multiple group assessments. The scores of component 3: 'Teaching and Assessment methods' can be found in Table 6.

Table 6: Weighted score Teaching and assessment methods and scores of sub-components

| Component | Maturity level | Sub-components | Score | Weight |
|---|---|---|---|---|
| 3. Teaching and Assessment Methods | 3,31 | | | |
| | | 3.1 Teaching based on real-life situations | 4 | 0,358 |
| | | 3.2 The use of an appropriate range of innovative teaching methods | 4 | 0,11 |
| | | 3.3 The use of students' existing knowledge and experience | 1 | 0,23 |
| | | 3.4 Multiple assessments of students' innovation competencies | 4 | 0,302 |

### *4.2.4 Component 4: Modes of teaching*

The whole first part of the minor is individual. Students learn the basics of innovating and are assessed on their individual knowledge.

During the second and third part of the minor, students work in duos and groups of three or four. However, also during these parts of the minor, students work individually as well. Examples are an individual report and a pitch.

Developer 1: *"…the toolbox also includes a pitch and the practical assignment, for example, still includes individual reflection, so we do have individual elements."*

*Analysis*

The balance between both individual and group assignments and assessments is discussed in the study of Pereira et al. (2016). It was stated that both types of learning and assessing should be implemented in a pedagogical system. This is the case for TIP. Moreover, (Vlachopoulos & Jan, 2020) explored the students' preferences towards modes of teaching in the post-COVID-19 era. It was found that an optimal balance of learning flexibility by both on-campus and live

streaming lecture delivery results in the most student satisfaction. Currently, TIP is focused on on-campus delivery. The scores of component 4, 'modes of teaching', can be found in Table 7.

Table 7: Weighted score Modes of teaching and scores of sub-components

| Component | Maturity level | Sub-components | Score | Weight |
|---|---|---|---|---|
| 4. Modes of Teaching | 4 | | | |
| | | 4.1 The opportunity for students to work both in groups and individually | 4 | 1 |

### *4.2.5 Component 5: Learning environment*

Two out of three developers underpinned the relevance of a positive relationship between students and teachers, without being asked a specific question on this subject. A positive and stimulating atmosphere is important to enable students to learn in an optimal manner. However, classrooms are not always suitable for the specific lesson that is given. One developer indicates that in an ideal situation, classrooms are scheduled conform the purpose of the lesson.

Developer 1: *"…these seem to be narrow corridors with the tables arranged in front of them as before and well, that does not invite interaction. We also have lecture halls, which are a bit larger and with rotating chairs, where you are completely stuck in the benches. On the other side we have a multifunctional room, as they say. Well, if you do something that fits with that, that's perfect. If you want a different kind of lesson, it is a very annoying classroom. So the purpose and type of room, yes, ideally you want that to be coordinated."*

Two out of three developers underpin the importance of a positive learning environment for students to operate in. One developer said that every stakeholder, including students, should be treated as equals. This enforces the cooperation between all stakeholders. Another developers talks about the importance of a positive environment where every students feels free to work freely and ask questions. Moreover, this developer tells that all students are equally valuable. Intrinsic motivation should be stimulated by having fun while working with TIP.

Developer 1: *"You have a lot to add as a person. This may include knowledge of certain substantive documents. But it can also be completely different. So that everyone can add his or her own contribution to innovation development and I think that just involves having fun..."*

Developer 2: *"And the business community doesn't have to say 'U' to me, nor do students. We want us all to be able to work together. So that learning environment, accessible and friendly, then I think you have a very nice learning environment."*

*Analysis*

Currently, developers have little to no influence on which classrooms are being used for different types of lectures. In an ideal situation, the type of classroom is fitted for the type of lecture that is given. In the physical space, students tend to pay more attention to the infrastructure, teaching equipment, etc. (Dai et al., 2023). Moreover, relevant literature shows that buildings should be well-designed and attractive colors should be utilized, indicating that other physical aspects of classrooms are significant when determining where lecture are given (Yang et al., 2013).

The results showed that teachers highly value the relationship and collaboration with students, classroom interaction, and communication. This corresponds with the research of (Dai et al., 2023). In this research, it was also found that teachers pay the most attention to the teaching process, and the teaching effect based on the communication and interaction with students. This approach towards guiding students in achieving their learning goals was also underpinned by Marzano (2003b). They also underpinned how teacher-student relationships provide an essential foundation for effective classroom management. However, this relationship is not built by leaving it to chance. Strategies supported by research should be applied to build strong teacher-student relationships (Marzano, 2003b). In table 8, the scores for the learning environment of TIP can be found.

Table 8: Weighted score Learning environment and scores of sub-components

| Component | Maturity level | Sub-components | Score | Weight |
|---|---|---|---|---|
| 5. Learning Environment | 3,75 | | | |
| | | 5.1 Development of a positive relationship between teacher and student | 3 | 0,25 |
| | | 5.2 Classroom atmosphere: Positive – stimulating - friendly | 4 | 0,75 |

### *4.2.6 Component 6: Student-centric learning environment*

Five out of six teachers indicated that students can use tools that are provided to them, but do not deeply understand them. They can see separate tools, but not the larger picture of the whole situation and how the tools are connected to each other. Three out of the six teachers and one developer suggested that students must be trained in understanding tools. This is supported by one of the clients. This would also help students to see the whole situation more clearly.

Teacher 4: *"No, but that's where the questioning comes in, because even with methodologies you actually have to ask questions: 'Have I got the right tool for what I want to do?' And I see students operating more at the level of coloring pictures. Then you have a pile of tools and well, we do something with them, we just put something together. That we might teach them that in a very targeted manner."*

3 out of the 4 clients indicated that students lose time at the start of the business case. According to one client, this is because students do not take initiative. Consequently, this leads to misunderstanding the assignment that a client delivers for the students and less time for students to finish the assignment. Therefore, according to one client, students should be more guided by clients and teachers, to prevent them from straying from the assignment.

Client 1: *"But you must remain the input and leading in matters, because if you don't do that, that is precisely the reason that they will go astray. The first time I went into business with your students, I was hardly approached or heard."*

Client 4: *"When I see the group of students we received, yes, I actually wondered whether most of those four students, if any, had any idea what they were doing and what we wanted, what we were asking for."*

Moreover, one teacher implies that not all learning material is as professional as is should be. Too much information is transferred to students through presentations and not through documents. One developer shares this opinion. Much learning material was constructed in Powerpoint and Excel. These learning materials are all available as standalone presentations, without supporting documents.

Teacher 2*: "These are the questions that arise and these are the tools and methods to investigate and answer them. But that's all in slides. So there's no working document or anything like that. They really have to get all those slides from that one lesson from TRL or*

*BRL to see, oh yes, these are all the options. So I think that some progress can be made there, that another document will follow that will reflect this much more clearly, in a bite-sized manner."*

Developer 1: *"You have companies, you have students, you have teachers, please let them work with professional material. We have now put everything together in Excel and PowerPoint and so on. But real progress can be made there."*

*Analysis*

According to the results, some students lack deeper understanding of the contents that are presented in the minor TIP. Campbell et al. (1998) explored the causes for this lack of understanding among students. It was found that two problems cause the lack of understanding among students. Firstly, curriculum overload has been named as a root cause for lack of understanding of learning materials. However, during data analysis, it was found that all students of TIP scored the workload of the minor TIP as the 'perfect amount'. Therefore, it is assumed that the cause of the lack of understanding among students is not caused by curriculum overload.

The other cause described by Campbell et al. (1998) is the lack of home study routine. It was found that students rarely spend as much time as teachers suggest on their study. This is also the case for students who follow the minor TIP. As can be seen in the results, only one student out of 18 acknowledged to have spent as much time as it was suggested by Saxion. By spending as little time as possible, students mostly focus on finishing assignments, without studying to actually understand the learning material. As a consequence, students will not retain the information for real-life applications. Again, by using a superficial approach, students will fail to acquire in-depth understanding of the learning material. It seems that this is also the case for TIP.

In this research, it was found that some students struggle with time-management. As a consequence, clients are left dissatisfied with the process. The desire for an optimal efficiency of time-management is spoken of. In the research of Ahmady et al. (2021), time-management was proven to have a significant impact on academic performance. Thus, time-management is a factor that should be improved upon to achieve maximal academic performance among students.

Some learning material lacks quality, is not easy to interact with, and is difficult to understand for students. Other learning material, like the reader where all the core information about TIP and its essence is explained, proved to be clear and well-supported by scientific theories. According to (Adegoke & Oni, 2015), learning material should be simple to interact with and should be understood by learners, so much that it should require minimal assistance from tutors. If students are unable to understand the learning material, they could get demotivated and score more poorly (Zabidi et al., 2017). The scores of component 6: 'student-centric learning environment' and its sub-components can be found in Table 9.

Table 9: Weighted score Student-centric learning environment and scores of sub-components

| Component | Maturity level | Sub-components | Score | Weight |
|---|---|---|---|---|
| 6. Student-centric learning environment | 2,71 | | | |
| | | 6.1 Observing and meeting the student learning needs and existing knowledge | 2 | 0,227 |
| | | 6.2 Enough time for students to fulfill tasks | 4 | 0,085 |
| | | 6.3 Guidance in time-management | 2 | 0,152 |
| | | 6.4 Learning material quality | 3 | 0,536 |

### *4.2.7 Component 7: Complexity*

While using TIP, students must work on real-life cases, provided by clients that agreed to work together with Saxion on these projects. According to all developers, the complexity of these cases is very high. However, through a well-developed structure and preparing students for these cases, they stay manageable.

Developer 2: *"... you are actually slowly being prepared for: 'Be careful, it's going to be hectic.' And I've never actually heard any complaints in those last weeks"*

Developer 3: *"The structure we offer with the framework is experienced as pleasant. Students and companies also indicate that they will use this more often in the future."*

However, this high level of complexity can lead to less motivation and confidence in some situations. According to one teacher, students are mostly intrinsically enthousiastic about the cases. When a task becomes more complex, students tend to partly lose their motivation. Two teachers tell that the start of these cases are very complex with a lot of loose ends to tie

together. Students often struggle with this, resulting in losing time at the start of the case. This is also supported by one of the developers.

Teacher 6: *"But above all, starting up and what do you start with? A lot of time is really wasted there, if they start on their own at all."*

Teacher 1: *"If it is too difficult, so to speak, then they quickly abandon it."*

Developer 1: *"Yes, if they don't have something to hold on to, they will flee, as I see it, into other things."*

*Analysis*

As discussed, the workload of the minor influences the willingness of students to take a superficial or deeper learning approach (Groves, 2005). Also, complexity can rise if the quality of learning material is not optimal (Zabidi et al., 2017). As Zhou et al. (2022) described, the complexity of a task significantly influences a students' confidence towards performing well. Studies have shown that students procrastinate when tasks are highly complex of nature (Ahmady et al., 2021). This behaviour can also be seen within the students of the minor TIP. At the start of the real-life case, the complexity is at its highest. Then, students are found to procrastinate and lose time, as described for component 6. However the application of real-life problems should not be avoided at all, a balance should be found between the complexity of the tasks and the support of students. This would increase the quality of time-management of students. The scores for component 7: 'Complexity' can be found in Table 10.

Table 10: Weighted score Complexity and scores of sub-components

| Component | Maturity level | Sub-components | Score | Weight |
|---|---|---|---|---|
| 7. Complexity | 3,15 | | | |
| | | 7.1 Using real-life – complex - and unpredictable cases | 4 | 0,142 |
| | | 7.2 Use an optimal balance between complexity and students' skills: Improvement of self-efficacy - Students' confidence towards the task complexity | 3 | 0,525 |
| | | 7.3 Maintain a challenging task: Students engagement - Students interest | 3 | 0,334 |

### *4.2.8 Component 8: Theoretical foundation*

The theoretical foundation of TIP started with one developer who created a set of starting points for novices to learn how to innovate systematically. These starting points were, initially, mostly based on experience of this developer, who is considered an expert on this subject. After establishing this, literature and these starting points have been connected to each other by the developers of TIP. This is an iterative process. Consequently, much literature was gathered and used for the theoretical foundation of TIP. However, one developer indicated that it remains a challenge to connect the expertise and experience of an expert with empirical support. Currently, much information of TIP has been backed by theory, but it remains a challenge to connect practice with theory.

Developer 2: *"We have tried to tie in a lot with literature that is already there, and with good reason. So much research has already been done into innovation management and, above all, a practical way of managing innovation. What is difficult about that is that there is also a lot of experience, for example from *name* who simply has a huge amount of innovation experience, who knows how things work, but that may not be immediately stated in a book, so that is always has been a difficult point. How you put that together."*

For TIP, a database with all theory that has been used for the theoretical foundation of TIP was made. In this database, it is challenging to find the information you are looking for. Two developers share the opinion that the structuring of all literature should be improved. One developer says that it is currently hard for outsiders to use this database and that this should be improved. Another developer indicates that improvements can be made through the development of one central database for all developers and teachers.

Developer 1: *"But I think it can be improved, that we can easily find what we found, what it was about. For example, I have all kinds of articles that I have highlighted. And well, I have a suboptimal system myself. *name* has that, *name* still has a piece, teachers themselves have things, so a nice central place of, this is the essential literature, so a core literature database or something like that. That would be very desirable."*

Developer 2: *"But if you ask me exactly that: then I really have to call *name* and then I'm sure he can tell me right away. But for an outsider, you can't just get into it straight away. It's there somewhere, I would have to say."*

Despite the troubles of uncentralized databases, the team of developers all indicated that the theory behind TIP is flexible and highly adaptive. According to two out of three developers, this is mostly due to the size of the team. With only three developers, decisions and changes are quickly made. According to one developer, this flexibility is important, because time is always limited. Therefore, quick decision making and adapting is important.

Developer 3: *"Everyone has their own task. This makes the team flexible in making adjustments about TIP as a whole and within education."*

When analyzing the theory that was used for the foundation of TIP, it stands out that developers chose to include readiness levels of Business, Demand, Manufacturing, and Technology. Other important factors for innovations like sustainability, regulations, and ethics are not included in TIP.

*Analysis*

*"To develop a theory of some phenomenon, we must first decompose our system into a set of relevant parts, and then specify the potential properties of those parts, the relationships between the parts, and the temporal dynamics by which those properties and relationships can change"* (Smaldino, 2020b). This is exactly how the foundation of TIP was built. This decomposition that is discussed, is the set of assumptions regarding what is being studied. Based on these assumptions, the theory should be build. Again, this is exactly how the foundation of TIP was created. These decompositions can lead to paradigm shifts (Smaldino, 2020a). Based on this knowledge, the foundation of TIP followed the exact path that was described by Smaldino (2020a) for building a strong theoretical foundation.

However, it was found that multiple improvements can be made regarding the maintenance of the database, where the theory for the foundation of TIP is stored. It showed to be messy and it lacks a clear overview of all scientific studies that back the theory behind TIP.

Also, despite the fact that the process of theory building was followed, TIP lacks on some important factors of an innovaion process. These are the sustainability, regulations, and ethics that are tied to an innovation. More on this can be found in section *"5.4 Case-specific managerial implication*s". The scores of component 8: 'Theoretical foundation' and its sub-components can be found in Table 11.

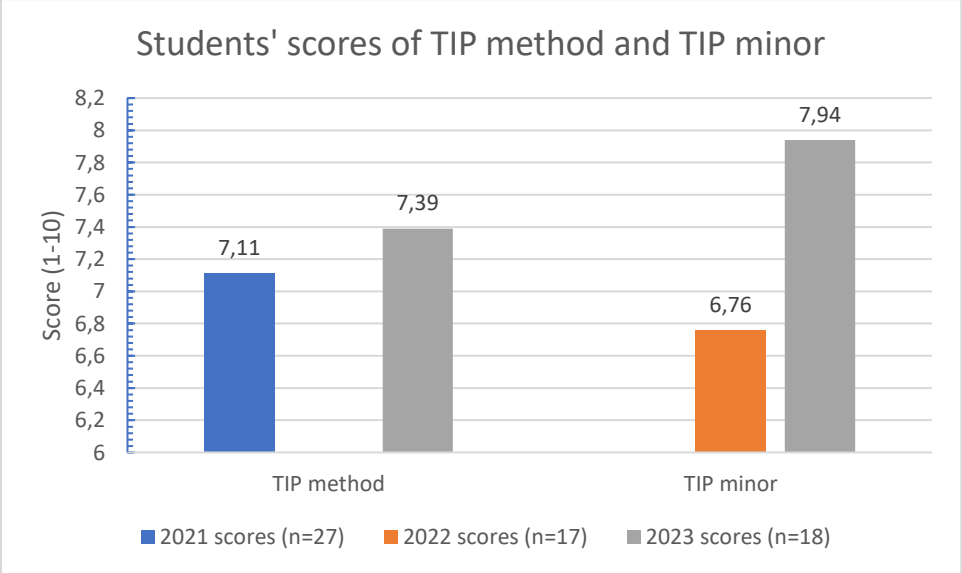
Table 11: Weighted score Theoretical foundation and scores of sub-components

| Component | Maturity level | Sub-components | Score | Weight |
|---|---|---|---|---|
| 8. Theoretical Foundation | 3,84 | | | |
| | | 8.1 Empirical support | 4 | 0,252 |
| | | 8.2 Relevance and applicability: The alignment of all theory with the goals and needs of the paradigm | 4 | 0,589 |
| | | 8.3 Flexibility/Adaptability | 3 | 0,159 |

### *4.2.9 Component 9: Quality Management*

Feedback from stakeholders is gathered through multiple manners. Feedback from students is gathered through two questionnaries. One about the whole minor and one about the TIP method itself. In these evaluations, it can be seen that students' satisfaction towards the minor has been improved over the last two years. In 2022, 17 students answered the questionary about the minor TIP. 4 students gave the highest score on how educational the minor was. The mean score for the minor, on a scale of 1 to 10, was 6.76. 4 students would recommend the minor to other students. In 2023, 18 students answered the questionary. 8 students gave the highest score on how educational the minor was. The mean score for the minor rised to a 7.94. 16 students would recommend the minor to other students. An overview of the scores that students gave to the tools used for TIP, the whole TIP method, and the minor can be seen in Table 2.

Figure 2: Students' scores of TIP method and TIP minor.



Additionally, process and content based feedback from teachers and clients is gathered through interviews about TIP and the minor TIP. This feedback is not structually analyzed. Adaptions based on feedback from all stakeholders is mostly done on the fly and through ad hoc decisions. One developer indicated that this feedback analysis should become more specific and more standardized in the near future.

Developer 3: *"...a more systematic and targeted process to obtain feedback and use it for improvements. In addition, the questions must be more targeted in these feedback documents."*

However, by being able to make decisions for changes on the fly, the developer enable themselves to be highly flexible. The small size of the team contributes to this flexibility as well.

Developer 1: *"I think we are a flexible team. Lots of things happen to everyone along the way, yes. But if something happens, we are on top of it. Then we act quickly and try to find a solution."*

During all interviews and the analysis of the questionaries, multiple points of improvement were suggested by all stakeholders. First, it was suggested by one of the developers that an expansion of the team of developers is needed. This would enable TIP to grow. Currently, too many lies on the shoulders of the developers and the question arises if TIP will survive if one or two developers would quit.

Developer 2: *"I think now, if one or two of our team leave, I'm like, 'yeah, I can't do this myself,' and then maybe it's just gone. And that remains the biggest challenge. Then TIP simply becomes a minor about innovation with a bit of structure."*

Secondly, a lack of communication leads to several types of problems. One teacher says that clients only have one spokesperson. If this spokesperson has trouble with the assignment as well, students will have trouble with concretizing the assignments of clients. Therefore, it was suggested to include another spokesperson from the clients, to enable more discussions and clarity among students and clients.

Teacher 1: *"Now they have one person they talk to, who sometimes doesn't understand everything as well. Yes, then it will be quite difficult. Because if it is difficult to fill in, it can go in any direction."*

Lastly, during data analysis, it becomes clear that not all teachers and clients possess a desired amount of knowledge regarding TIP. One developer revealed that lessons about TIP itself can only be given by the developers. Two teachers indicated that they do not have in depth knowledge about TIP as well. This also applies to clients. TIP is once or twice presented to clients, whereafter it is determined by the students and their communication towards clients whether they share all aspects of TIP with the clients or not. Two clients said that they have never seen the TIP framework or other tools, apart from the first presentation.

Developer 2: *"…but if it is also purely about teaching about TIP itself and about capturing innovation and how to do readiness level assessments; that almost depends on the few people who are really in TIP and I'm talking about me, *name* and *name*."*

Client 3: *"We never saw it (TIP framework) in this condition again."*

*Analysis*

As stated in the research of Walsh et al. (2002), key elements of quality management are continuous improvement and customer focus. In this case, the customers are the students that use TIP and the clients for who the real-life assignments are done during the minor. This corresponds with the findings of this study, where the importance of iterative improvement based on feedback from multiple stakeholders was underpinned. The mean score that students gave the minor TIP went from 6.76 in 2022 to 7.94 in 2023. This implies that the developers effectively used the feedback from 2022 to apply changes for the minor TIP. This utilization of the feedback loop leaded to a higher student satisfaction. The mean score of the TIP method itself did not rise as much. This indicates that developers prioritized the organization of the minor above improving the TIP method itself. Currently, plans are made to improve the TIP method itself, which are partly based on this research as well. Other suggestions for improvements were given, but these are case specific and went outside of the maturity assessment of TIP. These suggestions will be further discussed in part …. Case-specific managerial implications. The scores of component 9: 'Quality management' can be found in Table 12.

Table 12: Weighted score Quality management and scores of sub-components

| Component | Maturity level | Sub-components | Score | Weight |
|---|---|---|---|---|
| 9. Quality Management | 3,41 | | | |
| | | 9.1 Feedback analysis | 2 | 0,234 |
| | | 9.2 Improvements based on feedback | 4 | 0,278 |
| | | 9.3 Flexibility/adaptability | 4 | 0,365 |
| | | 9.4 Points of improvement | 3 | 0,124 |

### *4.2.10 Component 10: Tools*

Overall, the tools that are used for TIP are all relevant for each innovation stage. This is backed by 3 out of 3 developers, and 4 out of 6 teachers. However, two teachers indicate that mismatches exist between the TIP framework and the RLA. The coherence between these two tools is missing regarding some innovation stages. Some innovation criteria that are described in one innovation stage in the TIP framework, is described in another innovation stage within the RLA. According to three teachers, this leads to too much coherence between the two tools. A consequence of this is that students or teachers tend to not use one of these two tools throughout the minor TIP.

Teacher 3: *"You could physically make it into one document? That it is even clearer that it is related, so that you click on it, so to speak, and then you jump to the relevant tab in Excel where you can fill in those questions."*

Teacher 2: *"But that is because I regularly see some mismatches between the TIP matrix and the RLA, so there are things in a certain phase that are checked off in the first phase in the matrix, but they are not in the RLA, because that is indicated later and there are sometimes some differences and snags in terms of wording, which means that, yes, I actually do not see that matrix applied by myself and also the students."*

Teacher 6: *"I think that the first two, i.e. framework and readiness level, are already somewhat combined, but perhaps too much. The fact that there is now so much duplication that they only use one of the two…"*

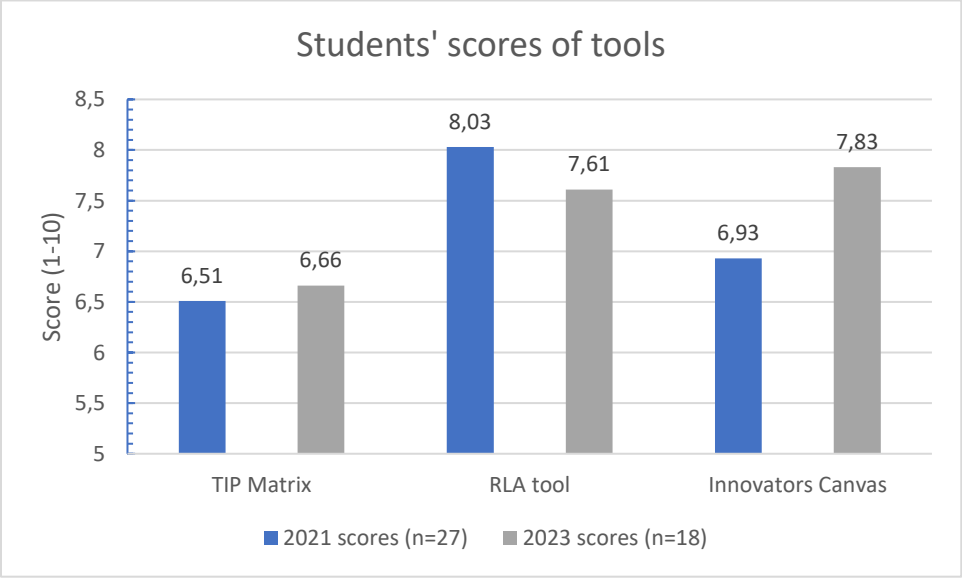
The three tools that are used for TIP provide the structure of the innovation stages together. These tools are coherent with each other. From the interviews with the teachers within the minor TIP, it becomes clear that the TIP matrix and the RLA tool are the most coherent. The

Innovators Canvas is the tool that provides an overview of the whole situation, where the TIP matrix and the RLA tool are more in-depth on the separate innovation stages. Therefore, one teacher suggested to keep the Innovators Canvas separate from the TIP matrix and the RLA tool.

Teacher 3: *"Yes, I would say you should keep those issues separate. And it's really a different angle. And that is what makes it so valuable."*

The TIP framework provides an overview of the whole innovation process. According to five out of six teachers, the TIP framework is understandable, easy applicable, and provides something to hold on to for novices through step-by-step documentation of the innovation process. This also helps with the motivation of students. When students have something to hold on to, it lowers the threshold to start working on tasks. In 2021, 27 students filled in the questionary on the TIP method. Here, the TIP matrix, the RLA tool, and the Innovators Canvas were scored on a scale from 1 to 10. The TIP matrix was scored a 6.51, the RLA tool was scored an 8.03, and the Innovators Canvas was scored a 6.93. In 2023, 18 students answered the questionary. The TIP matrix was scored a 6.66, the RLA tool was scored a 7.61, and the innovators canvas was scored a 7.83. In both questionaries, all students indicated that they would use TIP again for a next innovation problem. An overview of the scores that students gave for the tools that are used for TIP can be found in Figure 3.

Figure 3: Students' scores of tools



The RLA tool proves to have the potential to be the most valuable tool. However, the RLA needs the most improvements to reach this potential. Three out of six teachers and three out of four clients agree that the RLA tool provides the most in-depth insights out of al tools of TIP. However, according to two teachers, the chronological order of the RLA tool is not always correct. Several aspects that are described in the RLA must be filled in by students, before they should actually do this.

Teacher 2: *"I think we can still make some progress with the order in which things are placed...."*

Teacher 4: *"... 'a majority of anticipated customers indicate…', then you must have already done customer research, while you are not actually there yet, because you have not yet figured out who your customers are."*

In addition, according to four teachers, the RLA is too black and white for real-life situations as they are taught during the minor. One teacher suggests that in some situations, it is not necessary for all questions to be answered with 'yes', to move on to the next readiness level. Furthermore, some questions in the RLA tool that should be answered with a simple 'yes' or 'no', are more complex in real life. The option to make changes to the RLA tool tailored to the specific innovation situation is allowed, but is not done because this is too complex.

Teacher 6: *"That is stated in TIP, determine in advance: 'What will be the goals per readiness level?' So, when you start your project, you can make changes, but that doesn't happen."*

Teacher 4: *"This is also a yes-no question, and this is really a big research question."*

Teacher 3: *"And in this context, is such a question really so decisive that you say: 'I cannot continue, because I have not yet answered yes to that question?' Or is that perhaps in this context you say like, 'yes, actually hardly relevant.'"*

Lastly, the innovators canvas is also useful for an overview of the complete innovation process. With several tools, this canvas is filled in to decide which approach should be used for the innovation process.

*Analysis*

When analyzing the tools that are used for TIP, the scores that were given by students were used as the main determinant for scoring the tools in this maturity assessment. However, the

coherence between the TIP matrix and the RLA is too high to be used simultaneously. As also discussed in the analysis of the theoretical foundation, the TIP method provides well-grounded structure towards all innovation stages. The user experience of the tools has stayed more or less the same over the last years. Since these scores could be higher, these tools could still be improved. Following the data and analysis of the data, the scores for component 10: 'Tools' and its sub-components are presented in Table 13.

Table 13: Weighted score Tools and scores of sub-components

| Component | Maturity level | Sub-components | Score | Weight |
|---|---|---|---|---|
| 10. Tools | 3,13 | | | |
| | | 10.1 Relevance to the innovation stages | 4 | 0,122 |
| | | 10.2 Flexibility and adaptability | 4 | 0,245 |
| | | 10.3 Coherence between tools | 2 | 0,240 |
| | | 10.4 User experience | 3 | 0,158 |
| | | 10.5 Applicability for real-life situations (cases) | 3 | 0,236 |

### *4.3 Maturity of TIP*

After the analysis and scoring of all individual components of TIP, the overall maturity can be calculated. By using the AHP method, all components were weighted on relative importance. The overall maturity of TIP, as well as the weights of the individual components can be found in Table 14. The research question '*What is the current maturity of the individual components of TIP, following the maturity grid?'* was answered through this case study.

The findings of this case study indicate a positive impact of the TIP on students' innovation competencies. TIP serves as an effective platform for integrating and transferring theoretical knowledge, as well as supporting the application of this knowledge in practice. TIP holds the potential to promote a holistic view of an innovation process. However, to live up to this potential, multiple barriers should be removed. To accomplish this, more focus should be placed on students' comprehension of tools and their communication skills. Moreover, focus should be placed on the improvement of TIP itself, instead of the TIP minor. TIP is a valuable pedagogical initiative that successfully enhances innovation competencies. Though, the identified challenges highlight the need for constant improvements. More about this is discussed in section 5.4.

Table 14: Weighted Maturity Level of TIP

| Component | Maturity | Weight |
|---|---|---|
| 1. Innovation competencies | 3,11 | 0,188 |
| 2. Knowledge and skills | 2,50 | 0,153 |
| 3. Teaching and assessment methods and tools | 3,31 | 0,074 |
| 4. Modes of teaching | 4,00 | 0,057 |
| 5. Learning environment | 3,75 | 0,069 |
| 6. Student-centric learning environment | 2,71 | 0,057 |
| 7. Complexity | 3,15 | 0,239 |
| 8. Theoretical foundation | 3,84 | 0,038 |
| 9. Quality management | 3,41 | 0,032 |
| 10. Tools | 3,13 | 0,092 |
| **Overall maturity TIP** | **3,15** | **1.00** |

# 5. Discussion and conclusions

## *5.1 Main takeaways*

This research has revealed important insights regarding the maturity assessment of innovation platforms. It contributes to existing knowledge on maturity models and maturity assessment and opens up an unexplored field within current research: the maturity assessment of innovation platforms. Through rigorous data and literature collection, the trustworthiness of this research is assured.

The aim of this study was to create and a maturity model for innovation platforms and validate this tool with a case study on TIP. To do this, two research questions were formulated: '*How can the maturity of an innovation platform be measured?'*

To answer the first question, the developed maturity model is discussed. The maturity model shows potential for effectively assessing the maturity of innovation platform. Also, its real-life applicability was tested through a case study. This evaluation of the maturity model is in correspondence with (Hevner et al., 2004). The outcomes of this case study were used to improve the validity of the model. By doing this, an ongoing loop of iterative improvements is created. After multiple of these validation loops, the validity of the model will be increased. The maturity model now incorporates two elements. The first element is the innovation

platform as it is. The second element is the manner in which the platform and its ideas are transferred to its users. This idea of designing the maturity model is case-specific, opening a door for future improvements of the maturity model through enabling a more birds' eye perspective on an innovation platform.

The answer of the first research question is mainly answered in section 2.4, where the rationale behind the components of the maturity grid is explained. A literature study was conducted to gather knowledge about innovation platforms, maturity models, and the combination of the two. Before this study was conducted, a literature gap existed with regards to maturity models of innovation platforms. This study has closed this gap by creating a maturity model and a maturity grid for innovation platforms. After this research, this maturity model and maturity grid will enter their last phase of their design process: the maintenance phase (Maier et al., 2009).

Inductive results of the case study exposed the need for deleting and adding some components after data analysis. However, for further evaluation of the model, more methods for evaluation should be applied. In the future, interviews with experts on innovation processes should be conducted to evaluate the models' validity. Furthermore, more case studies should be conducted to improve the model.

It can be concluded that this maturity model evaluates innovation platforms. It incorporates components of an innovation platform and has the flexibility to be tailored for a specific innovation platform. Additionally, the tool exposes the strengths and points of improvements of an innovation platform, enabling developers to make guided decisions.

### *5.2 Theoretical implications*

This study adds value to existing literature by developing a maturity model for innovation platforms. The model builds on a review of existing literature on maturity models and the development of maturity models. Despite of using a foundation and methodology that has been widely accepted within maturity model research, this maturity model pioneers within the subject of innovation platforms. The synthesis of components, out of which an innovation platform exists, provides a new perspective on innovation platform maturity. Furthermore, this maturity model extends current literature by defining each phase of an innovation platform's lifecycle.

By rigorously using the design science guidelines of Hevner et al. (2004), the validity of the maturity model is secured. Also, by using theoretical insights, the tools relevance and

applicability in different contexts is assured. It should be noted that the use of theoretical insights is iterative as well, opening up the possibility that in the future, these theoretical insights could be altered.

Going further than just theory, this tool is applicable for real-world innovation platforms. By implementing this tool in an educational context, the aim is to explore its theoretical implication and the possibilities for further improvements. Within this educational context, the tool was developed with an user-centric approach. By creating a comprehensive and simple overview of the scoring system of all individual components, the ease of use of the maturity model is guaranteed.

Lastly, this model provides insights into the barriers and issues with current innovation platforms, but shows opportunities for improvements of the innovation platforms as well. By providing a method which uses weighted importance of each component, implications for improvements of an innovation platform are made case specific.

### *5.3 Practical implications*

This maturity model provides clear guidelines for organizations that seek to enhance their innovation platforms that are used for training or education. By identifying strengths and weaknesses of an innovation platform, opportunities for optimization are visualized.

Also, this tool acts as decision-making support. Every individual component is weighted for each specific case where the tool is applied. By doing this, well-informed decisions on further improvements of an innovation platform can be made. The strategies of the user of the tool are aligned with the tool itself, minimizing uncertainties.

### *5.4 Case-specific managerial implications*

When it comes to the case of TIP, several managerial implications can be made. To make targeted managerial recommendations, the AHP method that was carried out can be used.

For the focus on practical relevance, more targeted feedback from clients should be considered. Currently, clients deliver the real-life cases on which TIP is tested on. However, the clients do not have in-depth knowledge on TIP, resulting in a high risk of subjective assessment of the correlation between the use of TIP and innovation outcomes. For practical relevance, outcomes after the use of TIP should be considered. This can be done by conducting a pilot study, analyzing a group that uses TIP and a control group that does not use

TIP or uses a different approach towards an innovation problem. By doing this, the practical relevance of TIP is also analyzed, besides the theoretical relevance.

More emphasis should be placed on sustainability, ethics, and regulations when guiding an innovation process with TIP. Sustainability innovations have shown to increase a firms' competitive advantage, as well as increased value creation and reduced costs (Hermundsdottir & Aspelund, 2021). Fontrodona (2013) argues that ethics only inspires and encourages innovation, while laws on technology and on innovation can heavily influence an innovation process. If more emphasize is placed on these factors, the innovation processes that are guided by TIP will yield more value and reduce the costs of an innovation.

The main things that TIP should improve on, are the focus on the social skills of students and the students' understanding of the knowledge. These are mainly dependent on the complexity of the contents and the quality of the materials. These are also the components of TIP that are, according to the AHP method, scored as the most important by one developer of TIP.

Assessment methods should include activities that promote understanding next to superficial knowledge. These should include reflection, communication, investigation, debates (Unger, 1994). Three out of four assessment methods are already focused on for the TIP minor. Focus on communication skills is lacking. This can be concluded from the results of the case study, where multiple developers, teachers, and clients talked about the lack of communication skills. Being trained and assessed on communication skills, besides all other assessment methods, promotes a deeper learning approach of students (Campbell et al., 1998; Unger, 1994). However, as Campbell et al. (1998) stated, '*in order for students to understand something, they must first possess some knowledge about it.'* Foundational knowledge and understanding the knowledge are not mutually exclusive; a balance between the two must be sought and achieved.

This balance should be sought through a reconstruction of the curriculum. Currently, the workload is at a perfect level according to students. Workload is an important determinant for the approach students take towards learning (Groves, 2005). The workload is already balanced. This implies that other factors cause students to take a superficial approach towards learning.

In the case of TIP, this seems to be the complexity of the learning material. Teachers indicate that the quality of learning material should be improved by introducing more learning material on paper, instead of using mostly presentations. This learning material in the form of

documents should be clearly structured, making it easier for students to find the information they need. Moreover, the tools that are used as the foundation of TIP are currently too unclear for students to understand. The ease of use, and then mostly the combination of the tools, is too complex for students, resulting in misunderstanding the deeper essence and application of the tools. Therefore, a focus should be on refining these tools. In this case, the TIP matrix and the RLA should be refined in order to both have value in their own manner. At the moment, the use of one of both tools is often enough for students and teachers, while both tools have their own value. The duplications between the two tools should be reduced and the user-experience should be improved.

By improving these things, it is expected that students' knowledge and understanding will increase, as well as the innovation competencies and the complexity of both TIP and the minor TIP. These are the most important for the developers, following the results of the AHP method.

Other improvements deal with the other components of TIP. (Vlachopoulos & Jan, 2020) explored the students' preferences towards modes of teaching. It was found that students prefer a well-balanced mix between on-campus lectures and online study. Also, with regards to online study, students show a strong preference for pre-recorded lectures. Currently, TIP focuses on on-campus study. It is suggested that developers should look into the possibility of online lecturing, as an addition to the on-campus lectures.

As discussed, a high level of complexity can lead to poor time-management among students. Students procrastinate when tasks are too complex (Ahmady et al., 2021). Currently, during the minor TIP, students are more or less free to manage their time as they see fit. It is part of working on assignments that are complex from nature. However, at the start of the assignments, the complexity is at its highest. Here, it is preferred to guide students in their time-management. Proper time-management reduces stress and a reduction in stress leads to a higher confidence among students (Ahmady et al., 2021; Zhou et al., 2022). Therefore, it is suggested that time-management is more guided by teachers. This can be done through weekly deadlines for tasks. Moreover, teaching time-management rules, such as preventing postponement, pre- and reviewing data, prioritizing, and reviewing repeatedly are essential components for promoting efficient time-management (Hattie et al., 1996).

Lastly, the results exposed that not all teachers of TIP possess the foundational knowledge on TIP themselves. They are all experts on their own subject that is incorporated in TIP.

However, in order to transfer the ideas of TIP to students, a certain amount of knowledge and understanding of TIP is desirable. To guarantee this, a training for teachers should be set up, where the essence of TIP is explained and the roles between teachers is explained. This would increase the teachers' holistic understanding of TIP, as well as their expert knowledge of their own subject.

### *5.5 Limitations and future research*

This research does not come without limitations. Maturity models are sensitive for limitations (Ahmed & Capretz, 2011). This is also the case with this model. The first limitation deals with the completeness of the model. Although many dimensions were formulated, the chance remains that other factors influence a platforms' capability in guiding novices in innovating. As the research on the outcomes of the education of innovation is limited, the reported dimensions that were chosen might not be complete. A second limitation is the risk of subjective assessment. The scoring was done by only one researcher, resulting in no peer-reviewing of the scores. Moreover, by conducting a single case study, the generalizability of the model was limited. The model was mostly tailored to the context of TIP. Therefore, it may not seamlessly translate to other innovation platforms. By using the model in only one context, its applicability in other settings was not tested and thus not validated. Also, the analyzed data was divided over multiple stakeholders, imposing the risk that not all data is generalizable for all individual stakeholders.

For future research, it is recommended to conduct more research to validate the maturity model for innovation platforms. As it cannot be proven that this model is applicable for all innovation platforms, more research should be done on this subject. For further validation of the model, quantifiable data should be gathered to reduce the subjective assessment. Moreover, this research has failed to effectively and quantitatively capture the learning outcomes of students in the form of knowledge acquisition, skills, and competencies. Most data were qualitative, which leads to assumptions and subjective scoring. It is advised to further broaden this research, apply it to other innovation platforms in different contexts and different institutions. Nevertheless, this research has set an important and new basis for the maturity assessment of innovation that can be used to further explore this field of knowledge.

Also, further research should include the improvement of TIP by testing its practical and statistical significance. A study where the effect of TIP is tested quantitively in practice with a control group and an experimental group could be conducted to test the differences in

outcomes for the group that has used TIP and the group that did not use TIP. This would provide scientifical evidence of the practical relevance and value of TIP.

### *5.6 Conclusion*

In conclusion, this research has developed a robust tool to assess the maturity of innovation platforms. The tool has been grounded in theory and effectively measures various aspects of learning innovation. Through rigorous validation and evaluation, the tool proves to be reliable and valid for a case-specific cause. The study also highlights the theoretical and practical value, as well as managerial recommendations for improving an innovation platform. Other researchers are hereby invited to continue improving upon this tool and our understanding of innovation platforms.

# 6. References

Addessi, A. R. (2020). A Device for Children's Instrumental Creativity and Learning: An Overview of the MIROR Platform. *Frontiers in Psychology*, *11*, 11. https://doi.org/10.3389/FPSYG.2020.516478

Adegoke, B., & Oni, A. (2015). Teacher education systems in Africa in the digital era. *Teacher Education Systems in Africa in the Digital Era*, 1–306. https://doi.org/10.2307/J.CTVH8R00J

Ahmady, S., Khajeali, N., Kalantarion, M., Sharifi, F., & Yaseri, M. (2021). Relation between stress, time management, and academic achievement in preclinical medical education: A systematic review and meta-analysis. *Journal of Education and Health Promotion*, *10*(1). https://doi.org/10.4103/JEHP.JEHP_600_20

Ahmed, F., & Capretz, L. F. (2011). A business maturity model of software product line engineering. *Information Systems Frontiers*, *13*(4), 543–560. https://doi.org/10.1007/S10796-010-9230-8

Anderson, L., Hibbert, P., Mason, K., & Rivers, C. (2018). Management Education in Turbulent Times. *Https://Doi.Org/10.1177/1052562918779421*, *42*(4), 423–440. https://doi.org/10.1177/1052562918779421

Becker, J., Knackstedt, R., & Pöppelbuß, J. (2009). Developing Maturity Models for IT Management. *Business & Information Systems Engineering 2009 1:3*, *1*(3), 213–222. https://doi.org/10.1007/S12599-009-0044-5

Benner, P. (1982). From novice to expert. *American Journal of Nursing*, *82*(3), 402–407.

Bruin, T. de, Rosemann, M., Freeze, R., & Kulkarni, U. (2005). *Understanding the main phases of developing a maturity assessment model*. https://asu.elsevierpure.com/en/publications/understanding-the-main-phases-of-developing-a-maturity-assessment

Bucherer, E., Eisert, U., & Gassmann, O. (2012). Towards Systematic Business Model Innovation: Lessons from Product Innovation Management. *Creativity and Innovation Management*, *21*(2), 183–198. https://doi.org/10.1111/J.1467-8691.2012.00637.X

Campbell, D., DeWall, L., Roth, T., & Stevens, S. (1998). *Improving Student Depth of Understanding through the Use of Alternative Assessment.*

Casey, D., & Houghton, C. (2010). Clarifying case study research: examples from practice. *Nurse Researcher*, *17*(3), 41–51. https://doi.org/10.7748/NR2010.04.17.3.41.C7745

Chen, L., Bae, S. R., Battista, C., Qin, S., Chen, T., Evans, T. M., & Menon, V. (2018). Positive Attitude Toward Math Supports Early Academic Success: Behavioral Evidence and Neurocognitive Mechanisms. *Psychological Science*, *29*(3), 390–402. https://doi.org/10.1177/0956797617735528/ASSET/IMAGES/LARGE/10.1177_0956797617735528-FIG3.JPEG

Cooper, R. G. (n.d.). *Stage-Gate Systems: A New Tool for Managing New Products*.

Dai, Z., Xiong, J., Zhao, L., & Zhu, X. (2023). *Smart classroom learning environment preferences of higher education teachers and students in China: An ecological perspective*. https://doi.org/10.1016/j.heliyon.2023.e16769

Demir, C., & Kocaba, B. (2010). Project Management Maturity Model (PMMM) in educational organizations. *Procedia Social and Behavioral Sciences*, *9*, 1641–1645. https://doi.org/10.1016/j.sbspro.2010.12.379

Fontana, A., & Musa, S. (2017). The impact of entrepreneurial leadership on innovation management and its measurement validation. *International Journal of Innovation Science*, *9*(1), 2–19. https://doi.org/10.1108/IJIS-05-2016-0004/FULL/PDF

Fontrodona, J. (2013). The Relation Between Ethics and Innovation. *CSR, Sustainability, Ethics and Governance*, 23–33. https://doi.org/10.1007/978-3-642-36540-9_3/COVER

García-Mireles, G. A., Moraga, M. Á., & García, F. (2012). Development of maturity models: A systematic literature review. *IET Seminar Digest*, *2012*(1), 279–283. https://doi.org/10.1049/IC.2012.0036

Gislason, N. (2010). Architectural design and the learning environment: A framework for school design research. *Learning Environments Research*, *13*(2), 127–145. https://doi.org/10.1007/S10984-010-9071-X/FIGURES/6

Gottschalk, P., & Solli-Sther, H. (2009). Towards a stage theory for industrial management research. *Industrial Management and Data Systems*, *109*(9), 1264–1273. https://doi.org/10.1108/02635570911002315

Groves, M. (2005). Problem-based learning and learning approach: is there a relationship? *Advances in Health Sciences Education : Theory and Practice*, *10*(4), 315–326. https://doi.org/10.1007/S10459-005-8556-3

Hattie, J., Biggs, J., & Purdie, N. (1996). Effects of Learning Skills Interventions on Student Learning: A Meta-Analysis. *Source: Review of Educational Research*, *66*(2), 99–136.

Hermundsdottir, F., & Aspelund, A. (2021). Sustainability innovations and firm competitiveness: A review. *Journal of Cleaner Production*, *280*, 124715. https://doi.org/10.1016/J.JCLEPRO.2020.124715

Hero, L.-M., Lindfors, E., & Taatila, V. (2017). Individual Innovation Competence: A Systematic Review and Future Research Agenda. *International Journal of Higher Education*, *6*(5), 103. https://doi.org/10.5430/IJHE.V6N5P103

Hevner, A. R., March, S. T., Park, J., & Ram, S. (2004). Design Science in Information Systems Research. *Source: MIS Quarterly*, *28*(1), 75–105. https://www.jstor.org/stable/25148625

Hoidn, S., & Kärkkäinen, K. (2014). Promoting Skills for Innovation in Higher Education: A Literature Review on the Effectiveness of Problem-based Learning and of Teaching Behaviours. *OECD Education Working Papers*. https://doi.org/10.1787/5K3TSJ67L226-EN

Hong, W., Chan, F. K. Y., Thong, J. Y. L., Chasalow, L. C., & Dhillon, G. (2014). A Framework and Guidelines for Context-Specific Theorizing in Information Systems Research. *Information Systems Research*, *25*(1), 111–136. https://doi.org/10.1287/ISRE.2013.0501

Humphrey, W. S. (1987). *Characterizing the Software Process: A Maturity Framework*.

J., Kelley, F., & Watson, T. J. (1984). An iterative design methodology for user-friendly natural language office information applications. *ACM Trans. Inf. Syst.*, *2*(1), 26–41. https://doi.org/10.1145/357417.357420

Jia, G., Chen, Y., Xue, X., Chen, J., Cao, J., & Tang, K. (2011). Program management organization maturity integrated model for mega construction programs in China. *International Journal of Project Management*, *29*(7), 834–845. https://doi.org/10.1016/J.IJPROMAN.2011.03.003

Kleindorfer, G. B., O'Neill, L., & Ganeshan, R. (1998). Validation in Simulation: Various Positions in the Philosophy of Science. *Https://Doi.Org/10.1287/Mnsc.44.8.1087*, *44*(8), 1087–1099. https://doi.org/10.1287/MNSC.44.8.1087

Klimko, G. (2001). Knowledge Management and Maturity Models: Building Common Understanding. In *ECKM 2001 The 2nd European Conference on Knowledge Management* (Issue part 2). http://www.vits.org/publikationer/dokument/275.pdf

Kuhn, L. (2008). Complexity and Educational Research: A critical reflection. *Educational Philosophy and Theory*, *40*(1), 177–189. https://doi.org/10.1111/J.1469-5812.2007.00398.X

Ledgard, H., Gould, J. D., & Lewis, C. (1985). Designing for Usability: Key Principles and What Designers Think. *Communications of the ACM* , *28*(3).

Lee, A. (1999). Inaugural Editor's Comments. *MIS Quarterly*, *23*(1), 5–11.

Lee, C., & Benza, R. (2015). Teaching Innovation Skills: Application of Design Thinking in a Graduate Marketing Course. *Business Education Innovation Journal*, *7*(1), 43–50.

Maier, A., Moultrie, J., & Clarkson, P. J. (2009). *Developing maturity grids for assessing organisational capabilities: Practitioner guidance*. https://orbit.dtu.dk/en/publications/developing-maturity-grids-for-assessing-organisational-capabiliti

March, S. T., & Smith, G. F. (1995). Design and natural science research on information technology. *Decision Support Systems*, *15*(4), 251–266. https://doi.org/10.1016/0167-9236(94)00041-2

Marzano, R. J. (2003a). *Classroom Management That Works: Research-Based Strategies for Every Teacher.* Association for Supervision and Curriculum Development.

Marzano, R. J. (2003b). *The Key to Classroom Management*. https://www.researchgate.net/publication/283749466

Mettler, T., & Rohner, P. (2009). Situational maturity models as instrumental artifacts for organizational design. *Proceedings of the 4th International Conference on Design Science Research in Information Systems and Technology, DESRIST '09*. https://doi.org/10.1145/1555619.1555649

Miles, M. B., Huberman, A. M., & Saldana, J. (2014). Qualitative Data Analysis: A Methods Sourcebook. Third Edition. *SAGE Publications Ltd (CA)*.

Mirghani, H. M., Ezimokhai, M., Shaban, S., & van Berkel, H. J. M. (2014). Superficial and deep learning approaches among medical students in an interdisciplinary integrated curriculum. *Education for Health: Change in Learning and Practice*, *27*(1), 10–14. https://doi.org/10.4103/1357-6283.134293

Morse, J. (1994). Emerging from the data: The cognitive processes of analysis in qualitative inquiry. . *Critical Issues in Qualitative Research Methods*, 346. 350-351.

Moultrie, J., Clarkson, P. J., & Probert, D. (2007). Development of a design audit tool for SMEs. *Journal of Product Innovation Management*, *24*(4), 335–368. https://doi.org/10.1111/j.1540-5885.2007.00255.x

NEWBLE, D. I., & GORDON, M. I. (1985). The learning style of medical students. *Medical Education*, *19*(1), 3–8. https://doi.org/10.1111/J.1365-2923.1985.TB01132.X

Oke, A. (2007). Innovation types and innovation management practices in service companies. *International Journal of Operations and Production Management*, *27*(6), 564–587. https://doi.org/10.1108/01443570710750268/FULL/PDF

O'Sullivan, D., & Dooley, L. (2009). Applying innovation. *Applying Innovation*, 1–391. https://doi.org/10.4135/9781452274898

Pereira, D., Flores, M. A., & Niklasson, L. (2016). Assessment revisited: a review of research in Assessment and Evaluation in Higher Education. *Assessment & Evaluation in Higher Education*, *41*(7), 1008–1032. https://doi.org/10.1080/02602938.2015.1055233

Pöppelbuß, J., & Röglinger, M. (2011). What makes a useful maturity model? a framework of general design principles for maturity models and its demonstration in business process management. *European Conference on Information Systems*.

Rummler, G. A., & Brache, A. P. (2013). *Improving performance : how to manage the white space on the organization chart*. 270. https://www.perlego.com/book/1012351/improving-performance-how-to-manage-the-white-space-on-the-organization-chart-pdf

Saaty, T. (1980). *The Analytic Hierarchy Process (AHP) for Decision Making*.

Seawright, J., & Gerring, J. (2008). Case Selection Techniques in Case Study Research. *Http://Dx.Doi.Org/10.1177/1065912907313077*, *61*(2), 294–308. https://doi.org/10.1177/1065912907313077

Smaldino, P. E. (2020a). How to Build a Strong Theoretical Foundation. *Psychological Inquiry*, *31*(4), 297–301. https://doi.org/10.1080/1047840X.2020.1853463

Smaldino, P. E. (2020b). How to translate a verbal theory into a formal model. *Social Psychology*, *51*(4), 207–218. https://doi.org/10.1027/1864-9335/A000425

Tarhan, A., Turetken, O., & Reijers, H. A. (2016). Business process maturity models: A systematic literature review. *Information and Software Technology*, *75*, 122–134. https://doi.org/10.1016/J.INFSOF.2016.01.010

Temple, B., & Young, A. (2004). Qualitative Research and Translation Dilemmas. *Qualitative Research*, *4*(2), 161–178. https://doi.org/10.1177/1468794104044430

Tiwari, A., Chan, S., Wong, E., Wong, D., Chui, C., Wong, A., & Patil, N. (2006). The effect of problem-based learning on students' approaches to learning in the context of clinical nursing education. *Nurse Education Today*, *26*(5), 430–438. https://doi.org/10.1016/J.NEDT.2005.12.001

Tran, T. B. L., Ho, T. N., Mackenzie, S. V., & Le, L. K. (2017). Developing assessment criteria of a lesson for creativity to promote teaching for creativity. *Thinking Skills and Creativity*, *25*, 10–26. https://doi.org/10.1016/J.TSC.2017.05.006

Unger, C. (1994). What Teaching for Understanding Looks Like. *Educational Leadership*, *51*(5), 8–10.

Van Steenbergen, M., Bos, R., Brinkkemper, S., Van De Weerd, I., & Bekkers, W. (2010). The design of focus area maturity models. *Lecture Notes in Computer Science (Including Subseries Lecture Notes in Artificial Intelligence and Lecture Notes in Bioinformatics)*, *6105 LNCS*, 317–332. https://doi.org/10.1007/978-3-642-13335-0_22/COVER

Vlachopoulos, P., & Jan, S. (2020). Exploring modes of lecturing as a teaching method in higher education: Student attendance, preference and motivation. *Journal of University Teaching & Learning Practice*, *17*(5), 15. https://doi.org/10.53761/1.17.5.15

Von Wangenheim, C. G., Hauck, J. C. R., Zoucas, A., Salviano, C. F., McCaffery, F., & Shull, F. (2010). Creating software process capability/maturity models. *IEEE Software*, *27*(4), 92–94. https://doi.org/10.1109/MS.2010.96

Walsh, A., Hughes, H., & Maddox, D. P. (2002). Total quality management continuous improvement: Is the philosophy a reality? *Journal of European Industrial Training*, *26*(6), 299–307. https://doi.org/10.1108/03090590210431274/FULL/PDF

Wendler, R. (2012a). The maturity of maturity model research: A systematic mapping study. *Information and Software Technology*, *54*(12), 1317–1339. https://doi.org/10.1016/J.INFSOF.2012.07.007

Wendler, R. (2012b). The maturity of maturity model research: A systematic mapping study. *Information and Software Technology*, *54*(12), 1317–1339. https://doi.org/10.1016/J.INFSOF.2012.07.007

Yang, Z., Becerik-Gerber, B., & Mino, L. (2013). A study on student perceptions of higher education classrooms: Impact of classroom attributes on student satisfaction and performance. *Building and Environment*, *70*, 171–188. https://doi.org/10.1016/J.BUILDENV.2013.08.030

Yin, R. K. (2018). Case Study Research Design and Applications. *The Canadian Journal of Program Evaluation*, 319.

Zabidi, N. A., Woo, T. K., Rajesh Kumar, P., Fadzil, M., Hidayatul, S., & Husain, S. (2017). *Quality assurance in learning material development at OUM*. https://doi.org/10.1108/AAOUJ-01-2017-0014

Zelkowitz, M. V., & Wallace, D. R. (1998). Experimental models for validating technology. *Computer*, *31*(5), 23–31. https://doi.org/10.1109/2.675630

Zhou, X., Wang, X., & Liu, X. (2022). The impact of task complexity and translating self-efficacy belief on students' translation performance: Evidence from process and product data. *Frontiers in Psychology*, *13*, 911850. https://doi.org/10.3389/FPSYG.2022.911850/BIBTEX

# 7. Appendices

## *Appendix A: Tailored maturity grids for all assessment components*

Component 1: Innovation competencies

| Maturity Level | Description |
|---|---|
| Level 1: Initial | Novices are introduced to basic innovation skills and are encouraged to create simple creative solutions. |
| Level 2: Managed | Novices show improved creative thinking and are attempting more approaches to problems. |
| Level 3: Defined | Novices use a structured approach to innovation. The effectively use their creative skills and show a willingness to learn new perspectives. |
| Level 4: Quantitatively managed | Innovation competencies are quantitatively assessed. This allows a higher improvement in innovation skills every time the innovation platform is learned. |
| Level 5: Optimizing | Continuous improvement, novices are encouraged to continually improve their innovation skills, also after learning the innovation platform. This results in a broad range of effective and creative solutions. |

Component 2: Knowledge and skills

| Maturity Level | Description |
|---|---|
| Level 1: Initial | Novices begin to understand the basics of subject knowledge and cross-disciplinary topics. The emphasis lies on self-development. |
| Level 2: Managed | A structured approach is used to teach technical and social skills. Here, basic skills are taught to novices |
| Level 3: Defined | Novices acquire a fair amount of subject knowledge and cross-disciplinary understanding. Also, their social skills are tested, which enhances their ability to work in different teams and to give presentations. |
| Level 4: Quantitatively Managed | Novices are continuously assessed to provide insights to their progress. Targeted improvements are made to increase the knowledge and skills that novices acquire. |
| Level 5: Optimizing | Continuous improvements are made where novices constantly improve their skills with every task they perform. They leverage their learned technical and social skills. |

Component 3: Teaching and assessment methods and tools

| Maturity Level | Description |
|---|---|
| Level 1: Initial | Teaching mostly consists of traditional methods and the assessments are very simple. Few diversities in teaching. |
| Level 2: Managed | Teaching uses a variety of methods and assessments start to be more realistic. Still quite basic. |
| Level 3: Defined | Teaching is well-organized, uses different approaches and methods. Assessments are more centered around the skill of novices. |
| Level 4: Quantitatively Managed | The effectiveness of teaching is actively measured. Assessment methods are altered based on data-driven feedback. |
| Level 5: Optimizing | The use of innovative teaching methods and new ideas, and new assessments keep being improved to help novices improve their innovation skills. |

Component 4: Modes of teaching

| Maturity Level | Description |
|---|---|
| Level 1: Initial | Teaching is mostly based on individual competencies, with little group work. |
| Level 2: Managed | Students are introduced to working both individually and in groups. |
| Level 3: Defined | A balance exists between individual and group work, but the effectiveness of the balance is not measured. |
| Level 4: Quantitatively Managed | Both the effectiveness of working alone and working in groups is analyzed. Teaching strategies are adjusted to optimize both strategies. |
| Level 5: Optimizing | Teaching changes based on novices' reactions to working individual and in groups. Both strategies are optimally utilized and combined. |

Component 5: Learning environment

| Maturity Level | Description |
|---|---|
| Level 1: Initial | The learning environment is basic, with nearly no focus on creating a positive and stimulating classroom atmosphere. |
| Level 2: Managed | Efforts are made to create a positive and engaging learning environment, however not in a consistent manner. |
| Level 3: Defined | There is a focus on a positive and stimulating classroom atmosphere. Positive relations between teachers and students are encouraged. |

| | |
|---|---|
| Level 4: Quantitatively Managed | The impact of the learning environment on novices is quantitatively assessed and used to enhance classroom conditions. |
| Level 5: Optimizing | The learning environment is optimized based on insights and feedback from novices. Continuous improvement and innovation in learning settings. |

Component 6: Classroom management

| Maturity Level | Description |
|---|---|
| Level 1: Initial | Basic organization in the classroom, with low attention to student needs. |
| Level 2: Managed | Efforts are made to meet students' learning needs and time-management. |
| Level 3: Defined | Classroom management is structured to observe and adapt to students' learning needs. Plenty time is given to complete tasks. |
| Level 4: Quantitatively Managed | Classroom management is quantitatively analyzed and adjustments are made to enhance its efficiency based on the data. |
| Level 5: Optimizing | Classroom management is an innovative process, continually adapting to students' requirements. |

Component 7: Complexity

| Maturity Level | Description |
|---|---|
| Level 1: Initial | Learning tasks lack complexity and focus on merely basic ideas without much challenge. |
| Level 2: Managed | Tasks have some complexity, but it does not necessarily align with the novices' skills, resulting in a lower engagement. |
| Level 3: Defined | Tasks are more complex, considering the novices' skills, maintaining their interest and engagement. |
| Level 4: Quantitatively Managed | Complexity is measured based on novices' skills and analyzed to create an optimal balance between complexity and self-confidence. |
| Level 5: Optimizing | The complexity is continuously evaluated and optimized to create a challenging, but manageable level. This promotes high engagement and interest of novices. |

Component 8: Theoretical foundation

| Maturity Level | Description |
|---|---|
| Level 1: Initial | The theoretical foundation of the innovation platform is minimal, lacking empirical support and relevance to the platforms' goals. |
| Level 2: Managed | Some theoretical foundation exists, but it is not consistently aligned with the goals and needs of the platform. The platform shows low flexibility. |
| Level 3: Defined | The platform is based on a solid theoretical foundation, supported by relevant empirical evidence. It is flexible for changing needs and circumstances. |
| Level 4: Quantitatively Managed | Theoretical foundations are assessed and aligned with the platforms' goals, ensuring continuous empirical relevance and adaptability. |
| Level 5: Optimizing | Theoretical foundations are actively reviewed and refined, which allows for continuous alignment with the platforms' goals. It stays highly flexible for any changes in the scientific field. |

Component 9: Quality management

| Maturity Level | Description |
|---|---|
| Level 1: Initial | Feedback is not used for the improvement of the platform. |
| Level 2: Managed | Some efforts are made to analyze feedback, but improvements based on this analysis are not systematic or consistent. |
| Level 3: Defined | Feedback analysis is systematically conducted and improvements are made based on this analysis. |
| Level 4: Quantitatively Managed | Feedback analysis is quantitatively measured and used to make data-driven improvements, enhancing the effectiveness of the innovation platform. |
| Level 5: Optimizing | Feedback analysis is a continuous and data-driven process, leading to a dynamic and continuously improving innovation platform. |

Component 10: Use of tools

| Maturity Level | Description |
|---|---|
| Level 1: Initial | Tools are not systematically used in the platform and there is limited awareness or use of tools for the innovation process. |
| Level 2: Managed | Some tools are used in the platform, but the application is inconsistent. |
| Level 3: Defined | Tools are systematically integrated in the platform, a clear framework is used for the selection and use of tools. Feedback from tool usage is analyzed. |
| Level 4: Quantitatively Managed | Tool usage is quantitatively measured for effectiveness. Tools are continuously refined based on feedback. |
| Level 5: Optimizing | Tool are used in a continuously improved manner. Improvements are constantly made and the tool usage is seamlessly aligned with the innovation platform. |

## *Appendix B: Scoring sheet for the maturity assessment of innovation platforms*

| *Component* | *Description and sub-components* | *Score (maturity level)* 1 (Very poor) | 2 (Poor) | 3 (Fair) | 4 (Good) | 5 (Excellent) |
|---|---|---|---|---|---|---|
| **1. Innovation competencies** | 1.1 Innovative thinking skills | | | | | |
| | - Creativity | | | | | |
| | - Critical thinking | | | | | |
| | - Bravery of students | | | | | |
| | 1.2 Development of student curiosity | | | | | |
| | - Students ask questions | | | | | |
| | - Teachers ask questions | | | | | |
| | 1.3 Students' innovative products | | | | | |
| | - Creative answers | | | | | |
| | - Innovative ideas | | | | | |
| | - Innovative/new perspectives | | | | | |
| | 1.4 Positive attitude towards innovating | | | | | |
| | | | | | | |
| **2. Knowledge and skills** | 2.1 Technical skills | | | | | |
| | - Understanding of subject knowledge | | | | | |

| | | | | | | |
|---|---|---|---|---|---|---|
| | - Understanding of cross-disciplinary subject knowledge | | | | | |
| | 2.2 Social skills | | | | | |
| | - Communication | | | | | |
| | - (Cross-cultural) collaboration | | | | | |
| | - Teamwork | | | | | |
| | - Leadership | | | | | |
| | - Students' awareness of impact of appropriate behavior | | | | | |
| | - Presentation skills | | | | | |
| | | | | | | |
| **3. Teaching and assessment methods and tools** | 3.1 Teaching based on real-life situations | | | | | |
| | 3.2 The use of an appropriate range of innovative teaching methods | | | | | |
| | 3.3 The use of students' existing knowledge and experience | | | | | |
| | 3.4 Multiple assessments of students' innovation competencies | | | | | |
| | | | | | | |
| **4. Modes of teaching** | 4.1 The opportunity for students to work both in groups and individual | | | | | |
| | | | | | | |
| **5. Learning environment** | 5.1 Development of a positive relationship between teacher and student | | | | | |
| | 5.2 Classroom atmosphere: Positive, stimulating, friendly | | | | | |
| **6. Classroom management** | 6.1 Observing, meeting the student learning needs and existing knowledge | | | | | |
| | 6.2 Enough time for students to fulfill tasks | | | | | |
| | | | | | | |
| **7. Complexity** | 7.1 Using real-life, complex, and unpredictable cases | | | | | |
| | 7.2 Use an optimal balance between complexity and students' skills | | | | | |
| | - Improvement of self-efficacy | | | | | |
| | - Students' confidence towards the task complexity | | | | | |
| | 7.3 Maintain a challenging task | | | | | |
| | - Students engagement | | | | | |

| | | | | | | |
|---|---|---|---|---|---|---|
| | - Students interest | | | | | |
| | | | | | | |
| **8. Theoretical foundation** | 8.1 Empirical support | | | | | |
| | 8.2 Relevance and applicability | | | | | |
| | - The alignment of all theory with the goals and needs of the paradigm | | | | | |
| | 8.3 Flexibility/Adaptability | | | | | |
| | | | | | | |
| **9. Quality management** | 9.1 Feedback analysis | | | | | |
| | 9.2 Improvements based on feedback | | | | | |
| **10. Use of tools** | 10.1 Relevance to the innovation stages | | | | | |
| | 10.2 Flexibility and adaptability | | | | | |
| | 10.3 Coherence between tools | | | | | |
| | 10.4 User experience | | | | | |
| | 10.5 Applicability for real-life situations (cases) | | | | | |

## *Appendix C: Analytical Hierarchy Process outcomes*

In this appendix, the outcomes of the analytical hierarchy process are presented. For every comparison that was made, the number on the points in the sentence "*Row* is … times more important than *Column*" is shown. For example, in the table of the relative importance of components, *yellow Innovation competencies* is 4 times more important than *red Knowledge and skills*. Based on these relative importance scores, a weight is calculated that represents this importance. This is shown in the tables were the weight of the components and sub-components are presented. Component 4 is not shown in this overview, as this component does not have multiple sub-components. The consistency index is also shown next to the weights. A consistency index of less than 10% indicates objective scoring.

*Relative importance of components*:

| | 1. Innovation cor | 2. Knowledge a | 3. Teaching and | 4. Modes of tea | 5. Learning env | 6. Student-cent | 7. Complexity | 8. Theoretical fi | 9. Quality mana | 10. Tools |
|---|---|---|---|---|---|---|---|---|---|---|
| 1. Innovation competencies | 1 | 4 | 3 | 5 | 4 | 3 | 1/4 | 3 | 4 | 2 |
| 2. Knowledge and skills | 1/4 | 1 | 3 | 3 | 4 | 3 | 1/3 | 4 | 4 | 3 |
| 3. Teaching and assessment m | 1/3 | 1/3 | 1 | 2 | 1 | 2 | 1/3 | 2 | 2 | 1 |
| 4. Modes of teaching | 1/5 | 1/3 | 1/2 | 1 | 1/2 | 1/2 | 1/3 | 3 | 4 | 1/3 |
| 5. Learning environment | 1/4 | 1/4 | 1 | 2 | 1 | 1 | 1/3 | 2 | 3 | 1 |
| 6. Student-centric learning env | 1/3 | 1/3 | 1/2 | 2 | 1 | 1 | 1/3 | 2 | 1 | 1/2 |
| 7. Complexity | 4 | 3 | 3 | 3 | 3 | 3 | 1 | 4 | 5 | 3 |
| 8. Theoretical foundation | 1/3 | 1/4 | 1/2 | 1/3 | 1/2 | 1/2 | 1/4 | 1 | 2 | 1/4 |
| 9. Quality management | 1/4 | 1/4 | 1/2 | 1/4 | 1/3 | 1 | 1/5 | 1/2 | 1 | 1/3 |
| 10. Tools | 1/2 | 1/3 | 1 | 3 | 1 | 2 | 1/3 | 4 | 3 | 1 |

*Weights of components*:

| | AHP | | Consistency check |
|---|---|---|---|
| 1 | 0,188 | 18,8% | Consistency OK |
| 2 | 0,153 | 15,3% | 9% |
| 3 | 0,074 | 7,4% | |
| 4 | 0,057 | 5,7% | |
| 5 | 0,069 | 6,9% | |
| 6 | 0,057 | 5,7% | |
| 7 | 0,239 | 23,9% | |
| 8 | 0,038 | 3,8% | |
| 9 | 0,032 | 3,2% | |
| 10 | 0,092 | 9,2% | |

*Relative importance of sub-components of component 1:*

| | 1.1 Innovative thi | 1.2 Developmen | 1.3 Students' in | 1.4 Positive attit |
|---|---|---|---|---|
| 1.1 Innovative thinking skills | 1 | 2 | 2 | 3 |
| 1.2 Development of student cu | 1/2 | 1 | 2 | 1 |
| 1.3 Students' innovative produ | 1/2 | 1/2 | 1 | 2 |
| 1.4 Positive attitude towards in | 1/3 | 1 | 1/2 | 1 |

*Weights sub-components of component 1:*

| | AHP | | Consistency check |
|---|---|---|---|
| 1 | 0,416 | 41,6% | Consistency OK |
| 2 | 0,236 | 23,6% | 6% |
| 3 | 0,198 | 19,8% | |
| 4 | 0,150 | 15,0% | |

*Relative importance of sub-components of component 2:*

| | 2.1 Technical skills | 2.2 Social skills |
|---|---|---|
| 2.1 Technical skills | 1 | 1 |
| 2.2 Social skills | 1 | 1 |

*Weights of sub-components of component 2:*

| | AHP | | Consistency check |
|---|---|---|---|
| 1 | 0,500 | 50% | Consistency OK |
| 2 | 0,500 | 50% | 0% |

*Relative importance of sub-components of component 3:*

| | 3.1 Teaching base | 3.2 The use of ar | 3.4 Multiple asse | 3.5 Teachers knc |
|---|---|---|---|---|
| 3.1 Teaching based on real-life | 1 | 3 | 2 | 1 |
| 3.2 The use of an appropriate | 1/3 | 1 | 1/2 | 1/3 |
| 3.4 Multiple assessments of stu | 1/2 | 2 | 1 | 1 |
| 3.5 Teachers knowledge on the | 1 | 3 | 1 | 1 |

*Weights of sub-components of component 3:*

| | AHP | | Consistency check |
|---|---|---|---|
| 1 | 0,358 | 35,8% | Consistency OK |
| 2 | 0,110 | 11,0% | 2% |
| 3 | 0,230 | 23,0% | |
| 4 | 0,302 | 30,2% | |

*Relative importance of sub-components of component 5:*

| | 5.1 Positive relationship | 5.2 Classroom athmosphere |
|---|---|---|
| 5.1 Positive relationsh | 1 | 1/3 |
| 5.2 Classroom athmo | 3 | 1 |

*Weights of sub-components of component 5:*

| | AHP | | Consistency check |
|---|---|---|---|
| 1 | 0,250 | 25% | Consistency OK |
| 2 | 0,750 | 75% | 0% |

*Relative importance of sub-components of component 6:*

| | 6.1 Observing, me | 6.2 Enough time | 6.3 Guidance in t | 6.4 Learning mat |
|---|---|---|---|---|
| 6.1 Observing, meeting the stu | 1 | 3 | 2 | 1/3 |
| 6.2 Enough time for students t | 1/3 | 1 | 1/3 | 1/4 |
| 6.3 Guidance in time-managem | 1/2 | 3 | 1 | 1/5 |
| 6.4 Learning material quality | 3 | 4 | 5 | 1 |

*Weight of sub-components of component 6:*

| | AHP | | Consistency check |
|---|---|---|---|
| 1 | 0,227 | 22,7% | Consistency OK |
| 2 | 0,085 | 8,5% | 9% |
| 3 | 0,152 | 15,2% | |
| 4 | 0,536 | 53,6% | |

*Relative importance of sub-components of component 7:*

| | 7.1 Using real-life, | 7.2 Use an optim | 7.3 Maintain a cl |
|---|---|---|---|
| 7.1 Using real-life, complex, an | 1 | 1/3 | 1/3 |
| 7.2 Use an optimal balance bet | 3 | 1 | 2 |
| 7.3 Maintain a challenging task | 3 | 1/2 | 1 |

*Weights of sub-components of component 7:*

| | AHP | | Consistency check |
|---|---|---|---|
| 1 | 0,142 | 14,2% | Consistency OK |
| 2 | 0,525 | 52,5% | 6% |
| 3 | 0,334 | 33,4% | |

*Relative importance of sub-components of component 8:*

| | 8.1 Empirical supp | 8.2 Relevance an | 8.3 Flexibility/Ac |
|---|---|---|---|
| 8.1 Empirical support | 1 | 1/3 | 2 |
| 8.2 Relevance and applicability | 3 | 1 | 3 |
| 8.3 Flexibility/Adaptability | 1/2 | 1/3 | 1 |

*Weights of sub-components of component 8*

| | AHP | | Consistency check |
|---|---|---|---|
| 1 | 0,252 | 25,2% | Consistency OK |
| 2 | 0,589 | 58,9% | 6% |
| 3 | 0,159 | 15,9% | |

*Relative importance of sub-components of component 9:*

| | 9.1 Feedback anal | 9.2 Improvemen | 9.3 Flexibility/ad | 9.4 Current poin |
|---|---|---|---|---|
| 9.1 Feedback analysis | 1 | 1 | 1/2 | 2 |
| 9.2 Improvements based on fe | 1 | 1 | 1 | 2 |
| 9.3 Flexibility/adaptability | 2 | 1 | 1 | 3 |
| 9.4 Current points of improver | 1/2 | 1/2 | 1/3 | 1 |

*Weights of sub-components of component 9:*

| | AHP | | Consistency check |
|---|---|---|---|
| 1 | 0,234 | 23,4% | Consistency OK |
| 2 | 0,278 | 27,8% | 2% |
| 3 | 0,365 | 36,5% | |
| 4 | 0,124 | 12,4% | |

*Relative importance of sub-components of component 10:*

| | 10.1 Relevance to | 10.2 Flexibility a | 10.3 Coherence | 10.4 User experi | 10.5 Applicabilit |
|---|---|---|---|---|---|
| 10.1 Relevance to the innovati | 1 | 1 | 1/2 | 1/2 | 1/3 |
| 10.2 Flexibility and adaptabilit | 1 | 1 | 1 | 3 | 1 |
| 10.3 Coherence between tools | 2 | 1 | 1 | 2 | 1 |
| 10.4 User experience | 2 | 1/3 | 1/2 | 1 | 1 |
| 10.5 Applicability for real-life s | 3 | 1 | 1 | 1 | 1 |

*Weights of sub-components of component 10:*

| | AHP | | Consistency check |
|---|---|---|---|
| 1 | 0,122 | 12,2% | Consistency OK |
| 2 | 0,245 | 24,5% | 7% |
| 3 | 0,240 | 24,0% | |
| 4 | 0,158 | 15,8% | |
| 5 | 0,236 | 23,6% | |