

An Adaptive Model for the Development of Managerial Competencies in the Domain of Artificial Intelligence

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Abstract. Artificial Intelligence (AI) dramatically changes the way business is done today. It provides significant opportunities for operational improvements, increased speed and efficiency and shorter time-to-market. Yet the use of AI also raises ethical, legal and security concerns. In order to realize its benefits and avoid its pitfalls, managers need to understand the main concepts, tools, and techniques available to them in the AI domain of knowledge. They need to become skilled at validating the multiple business cases of using AI in their specific domain, but also at avoiding wrong AI investment decisions. Managers need to be open to experimenting with AI but also educate themselves and the other stakeholders of their business on having realistic expectations from the adoption of AI.

The competencies that managers need to develop in the domain of AI, regardless of their role and business function they operate in, has become subject of increased research recently. We have also answered to a few related research questions in our previous papers: “What do managers need to know in the area of Artificial Intelligence?” [1] and “How to organize the AI domain of knowledge to be fit for tutoring managers” [2] or “What could be a proper architecture for an Intelligent Tutoring System for business” [3]. In this paper, we investigate the actual process of developing AI managerial competencies by the use of Intelligent Tutoring Systems (ITS). We thus search the answer to the following specific research question: “How can the process of AI managerial competencies development be accelerated by using adaptive learning technologies?”

At this stage, this work is based on desktop research of the topic and is proposed for further discussion. The model can only be tested and quantitatively explored once we develop the first prototype of the ITS.

Keywords: Artificial Intelligence, AI Managerial Competencies, Leadership Development, Intelligent Tutoring Systems, Adaptive Learning Technologies.

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Introduction

The recent development of powerful large language models (LLM) and foundational, large reasoning models (LRM) has reignited the discussions around the massive transformative potential of Artificial Intelligence in business.

If managers want to improve their effectiveness and increase the competitiveness of their companies they seem to have no other alternative but to understand and start using responsibly these new tools in their particular role, regardless of the business function they manage (marketing, HR, finance, operations, etc). Managers also need to understand the AI-specific risks and the emerging regulatory framework, as well as learn how to test and validate the valuable AI use cases in their own industry and field of activity.

In order to increase their productivity in using these new tools and technologies, both at a personal level and across the organization, managers need to develop a series of new competencies [4]. They must understand the basic factual, conceptual, procedural and metacognitive knowledge components [5] of the Artificial Intelligence domain, but also develop a series of skills, attitudes and other personal characteristics that facilitate the improvement of their job performance [6]. These specific competencies in the domain of Artificial Intelligence also allow managers to take informed decisions regarding their personal and organizational investment in AI and facilitate experimentation and testing the multiple value benefit hypotheses.

Our long-term research question is formulated around using these powerful new AI tools and technologies in helping managers develop their managerial competencies required for AI adoption. In previous papers, we have already answered specific questions like:

- “What do managers need to know in the area of Artificial Intelligence?” [1]
- “How to organize the AI domain of knowledge to be fit for tutoring managers” [2]
- “What could be a proper architecture for an Intelligent Tutoring System for business” [3]

In this paper we focus our attention to the process of developing the competencies included in the proposed *AI Managerial Competencies Framework* [1] by the use of Intelligent Tutoring System’s adaptive technology. This approach allows for intensive personalization of the competence development process, an endeavor that is expected to provide increased efficiency of the learning and personal development process [7].

As such, our research question for this paper is:

- *How can we accelerate the process of AI managerial competencies development by using adaptive learning technologies?*

This work thus builds on our previous work, leveraging on the concepts researched so far and addressing topics like (i) the personalization algorithm, (ii) tutoring strategies, and (iii) split of the development process in an “outer” and an “inner” loop.

Literature review

Managerial AI competency frameworks

The competencies managers need to develop in the domain of Artificial Intelligence has been subject to recent research by several authors.

One of the first attempts to develop an AI competency framework was performed in 2021 by Concordia University and Dawson College, a project financed by *Pôle montréalais d’enseignement supérieur en intelligence artificielle* (PIA)[8]. The framework defined a list of technical, business, and human competencies grouped in 13 themes: *Data, Mathematics and Statistics, Programming, Machine Learning, Deep Learning, Infrastructure, Libraries and Frameworks, AI Initiative and Project Planning, AI Initiative and Project Scaling, AI Technologies, Innovation, Teamwork, Professionalism*.

Another relevant example is the work of Yannick Peifer and Sebastian Terstegen called “*Artificial Intelligence - Qualification and Competence Development Requirements for Executives*”[9]. They introduce the concept of AI qualification as developed and tested within the en[AI]ble project funded by the German Federal Ministry of Labor and Social Affairs (BMAS).

In a paper called “*Artificial Intelligence-Enabled Business Model Innovation: Competencies and Roles of Top Management*” Jorzik et al. took an inductive qualitative approach (based on interviews with a wide series of professionals) to look at the way AI could be integrated in new, innovative business models [10]

The topic of AI Literacy [11] [12] is also touching on the topic of AI competencies but rather generally applicable competencies, and not necessarily focusing on the competencies that contribute to business management professionals’ effective job performance.

The development of managerial competencies

Numerous studies have shown that personalized tutoring of pupils and students, both physically and with the help of digital ITS tools, increases the learning rate [7] [13]. When it comes to adult personal development:

A scientific research report published in 2021 by David Day et. al shows that, while the training addressed to managers is more targeted, aiming to address specific technical or organizational topics (such as new policies or technologies used in the company) or to remedy problems identified in the performance of the manager and/or his/her team, the professional development programs of a leader address a longer path. These programs are based more on the experience acquired through practice and are focused on the acquisition of the competences of leaders to deal with unforeseen situations[14].

These conclusions are aligned with extensive research performed by representatives of the experiential learning school of thought introduced by David A. Kolb together with Ron Fry through **the Experiential Learning Model (ELM)** in the early 1970s. The model explains the accumulation of new skills through a 4-step cycle:

1. Concrete experience
2. Observation and reflection on the experience
3. Forming abstract concepts based on the reflections in step 3
4. Experimental testing of formulated concepts

Later, David Kolb developed the **Learning Style Inventory (LSI) tool**, which is now in version 4.0[15]. It explains the development of competences along two axes: Active Experimentation – Reflective Observation and Abstract Conceptualization – Concrete Experience, thus defining 9 learning styles.

A similar learning model (**70/20/10**) was formulated by McCall, Lombardo and Eichinger in 1996 who identified that 70% of learning is achieved by taking on difficult/challenging practical tasks and the remaining 20% from human relationships and 10% from courses and training [16].

Use of AI in education (AIED)

The use of Artificial Intelligence (AI) in building intelligent tutoring systems (ITS) that can personalize education was proposed as early as 1970 by Jaime Carbonel[17]. The term Intelligent Tutoring Systems (ITS) was introduced by D. Sleeman and J.S. Brown in 1982 [18] in their collection of scientific papers in the domain of AI in education (AIED). Published under the name “Intelligent Tutoring Systems”, the authors review a few intelligent systems that are grouped into four categories: 1) problem solvers, 2) coaches, 3) lab instructions and 4) consultants.

A reference architecture of the Intelligent Tutoring Systems has been defined in 1980s [19] and while today there is a wide range of architectures powering ITS systems in the market[20], this architecture is useful for analyzing and clarifying conceptual aspects regarding the development of adaptive ITSs. This reference architecture is based on four functional blocks: a model of the knowledge domain, a way of tracking learner knowledge & learning progress (the user model), a tutoring module and a communication & interfacing module.

Methodology

At this stage, we are proposing an adaptive model for the professional development of managers in the field of Artificial Intelligence. The model integrates elements from the *Theory of Knowledge Spaces*[21], the extensive research/literature on topics related to the development of Intelligent Tutoring Systems (more specifically the *Knowledge Tracing* algorithms), and the literature specific to the development of managerial competency frameworks.

The proposed model is thus based on desktop research and experience of the authors. It can only be further assessed and quantitatively explored once we develop a first prototype of the ITS and after executing a pilot such as to gather enough usage data points for statistical analysis.

We followed the following phased approach in designing the proposed model:

(1) Structuring the field of knowledge, respectively defining a *knowledge space* specific to the domain of Artificial Intelligence in the sense defined by Doignon and Falmagne in the *Theory of Knowledge/Learning Spaces*[21]. The knowledge space models the structure of the domain of Artificial Intelligence, by identifying the components of knowledge and the nature of the relationships (e.g. precedence) between these concepts. It thus defines the content and the hierarchy of subjects that make the curricula for the professional training of managers.

An important sub-step of this first stage is the identification of *potential/feasible states* in the knowledge space. These states represent valid configurations of knowledge components, ordered according to the possible relationships between the concepts specific to the field of knowledge (e.g. the dependence of higher-order knowledge on the prior understanding of lower-order information, classifications, methods, working techniques, etc.).

Knowledge states thus represent collections of knowledge components that can be accumulated over time, starting from an initial state that defines “total lack of knowledge” (novice state) to “expert-level knowledge”. The *Theory of Knowledge spaces / Learning Spaces* [21] shows that only certain states made up of specific sets/collections of knowledge elements are valid and can be part of a *learning space*.

(2) Defining the set of *competencies* – valid configurations of knowledge, skills, attitudes, and other relevant personal characteristics – specific to each management role. These competencies were defined according to the specific needs and responsibilities of the role, respectively the tasks that a business management professional must perform within the role. For each of the role categories we designed competencies for, namely *top management*, *middle management* and/or *line management*, the components of each competency must be evidenced at different levels of performance depending on the seniority in the role. These competency levels represent the target states that each learner will have to achieve through learning and skills training.

(3) Identification of specific methods for *diagnosing the current level of knowledge/skills* of a manager (a.k.a *Knowledge Tracing*). These methods aim to identify the actual *knowledge state* of each manager, respectively its position in the *learning space*.

This diagnosis allows us to define an *adaptive algorithm* for the selection of the relevant *tutoring strategy* that drives the development process effectively. These strategies may point to the elements of the knowledge/learning space that need to be presented next to the manager, at each stage of its competence

development process or else recommend the appropriate type of intervention in the learning context of each stage/manager (e.g. encouraging conversations, corrective and/or motivational feedback, review of specific elements of knowledge, etc.).

(4) The last stage in the development of the model is represented by the testing / validation of the adaptive model by implementing an iterative cycle of the DO-CHECK-ACT type, respectively a feedback loop from users that allows the improvement of the algorithm in successive/incremental iterations. This stage will be the subject of a future stage and is dependent on the development of a minimum viable ITS tool.

Results and further discussions

A model for the adaptive training of managers in the field of Artificial Intelligence

In Figure 1 below we present the conceptual flowchart of the proposed process for the adaptive training of managers in the field of Artificial Intelligence. The process is built on various concepts from the learning management and ITS (intelligent tutoring systems) development literature as referenced below.

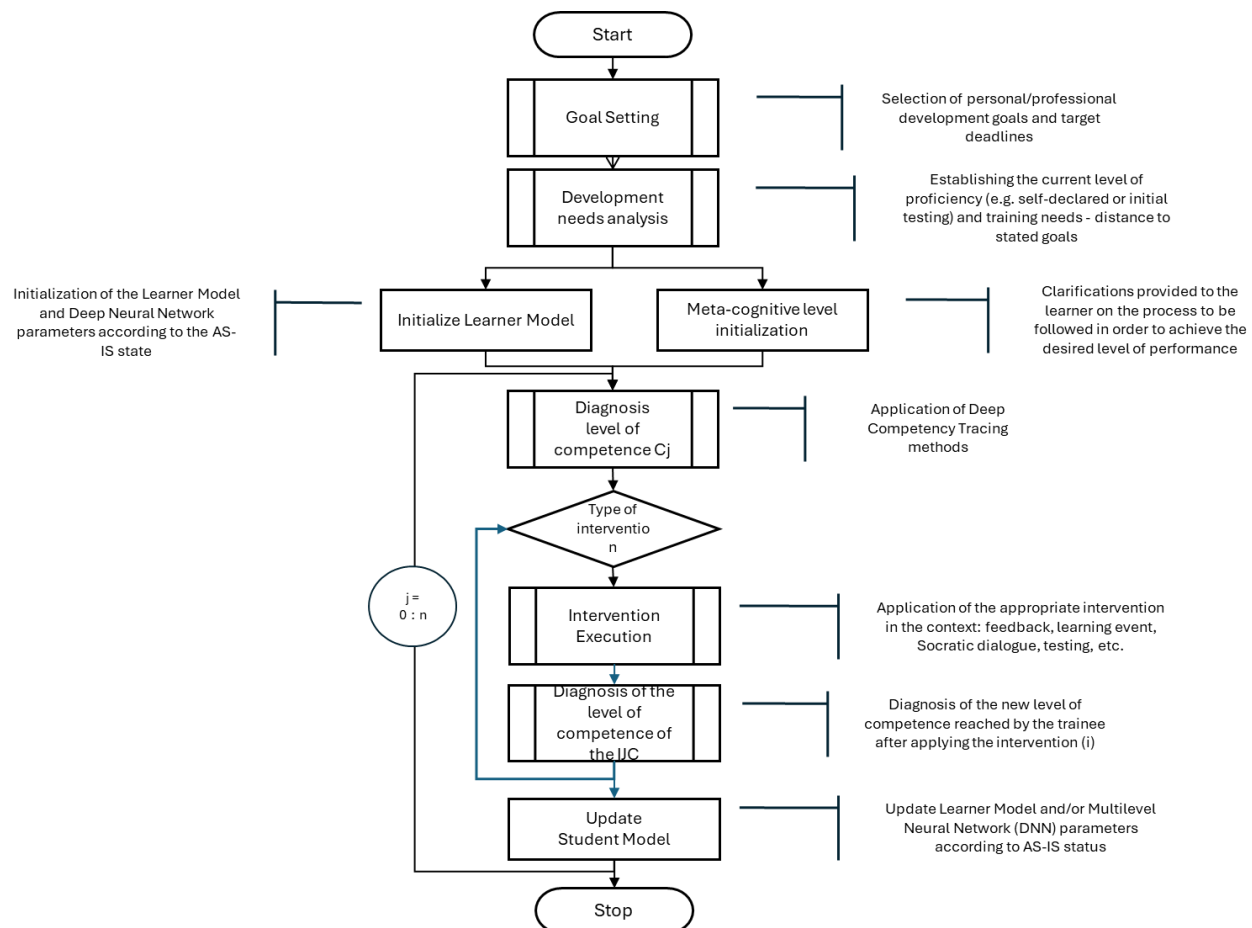


Figure 1: Algorithm for the adaptive training of managers in the field of Artificial Intelligence

Source: Authors' own contribution

(1) **Goals Setting:** the process of personalized training starts with the establishment of development objectives targeted by the learner[22].

The specific goals and objectives of each manager can be self-declared - e.g. selected from a predefined list, or can be subject to an assisted process - whether by an expert or by an AI-enabled virtual assistant (e.g. chatBOT). The manager will be thus guided towards defining a target professional state, according to the current role and career

development aspirations. Corresponding to this target state/role, specific development objectives will be formulated in natural language and using a vocabulary that is accessible to the learner. Internally, these objectives are broken down into a set of target competences as per the ontology defined in the managerial AI competency framework.

Therefore, the first step in the process will be the execution of a procedure of "*setting goals & objectives*" that is independent of the current proficiency of the manager in the domain of Artificial Intelligence.

Other factors relevant in the development process can be identified in this step, such as a set of preferences of the learner. These could address preferred learning style, urgency and time allocated to personal development, etc.

(2) **Analysis of Development Needs:** In the next step, an analysis of development needs will be made. This step involves carrying out an initial diagnosis of the current level of competence in the field of AI and/or the level of seniority/performance of the learner. The diagnosis will track both the level of *knowledge*, and the level of performance in the application of knowledge in solving tasks specific to the target role (*skills*). An important element that affects the effectiveness of the manager in the specific context of his/her role, is also the level of motivation and personal views and interests[4]. This level of motivation will be further manifested as a willingness of the trainees to actively engage in the development process as well as the completion rate of specific activities, development tasks and homework.

By assessing the differences between the current level of competence and the previously established objectives, the initial hypotheses regarding the *development needs* will be identified: theoretical training, practice/application scenarios/problem solving, motivational coaching, etc.

Similar to the previous step of establishing goals and objectives, the diagnosis can be made either by a simple self-assessment of knowledge, skills, attitudes and other relevant personal characteristics, based on answering questions such as "On a scale of 1 to 10 how well ...", or by performing a more elaborate assisted and/or automated assessment step.

Therefore, the areas of development to be addressed will be established at this stage: knowledge, skills, habits and attitudes, motivations, etc. These initial assumptions regarding training needs will be calibrated/corrected later in the iterative competence development sessions.

(3) **Learner Model Initialization:** following the diagnosis of the current level of competence in relation to the established objectives, the initialization of the learner model can be performed, an internal model of the adaptive training application that defines and follows the evolution of the learner's knowledge, skills and attitudes development over time.

(4) **Metacognitive Level Initialization:** at the same time, the metacognitive level of the learner is initiated, according to the results of the initial diagnosis. The metacognitive level has an important role in managing expectations and motivating the learner through support and assistance/tutoring mechanisms.

The gap between the current level of competences in the diagnosed AI field and the target level to be achieved through training - on different competences identified in the competence model – as well as the alternative possible ways/processes/means to address this difference in an effective way are now explained to the manager. Different intervention strategies can be thus triggered in this step – motivation, guidance, challenge – in relation to the manager's profile/maturity and learning preferences.

Steps 1-4 represent the initialization stage of an "*outer loop*"[23], a development process that spans several training sessions and several development cycles, respectively. This is the long-term view of the evolution of each manager in the development process.

Within this loop, repetitive development sessions will be organized as set out in the needs analysis phase and according to the development strategy (tutoring module): for each target competence C_j , "*inner loops*" of development will be executed[23]. This are training sessions specific to the components of competence that need development (knowledge, skills, attitudes or other components), namely iterations of target competence(s) development. Steps 5 – 9 are specific to each one of these inner loops:

(5) **Diagnosis of Competence C_j Level:** Detailed diagnosis of the level of performance in the C_j competence. At the first iteration, this step may consist of the initial, high-level view of the level of proficiency in competence C_j as initialized in step 2, or a more detailed diagnosis of the specific level of performance in regards to the competence C_j tested in this iteration/session.

This diagnosis may cover a test of the constituent knowledge components, or its corresponding skills, namely applying this knowledge in practice, in solving situations/problems specific to the individual profile of the learner. The diagnosis should also cover the assessment of other elements (e.g. personal characteristics of a manager) relevant to this particular competence C_j . In the following iterations, the proficiency level will be imported directly from the student model, stored in the manager's application profile.

Diagnosing the actual, real level of specific knowledge of a manager can be performed by using one of the several models available in the scientific literature, collectively known as *knowledge tracing* algorithms. These are either *probabilistic models* that account for potential/probabilities of lucky guesses and errors/mistakes or other types of models like the *cognitive architectures* (e.g. *ACT-R**, *SOAR*), or the ones based on *artificial intelligence networks* (e.g. *Deep Knowledge Tracing*).

(6) **Tutoring Module:** A *tutoring module* establishes the appropriate type of intervention for each step according to the development context (e.g. testing results).

In the case of failed tests several different tutoring strategies may prove their effectiveness: Socratic dialogues, scaffolding, initiating learning micro-sessions and/or referencing specific content topics, referencing specific case studies relevant for the topic, asking for solutions to role and competency-specific challenges etc.

Even in the case of successful test results specific tutoring strategies like reinforcing positive feedback may increase manager's confidence level and thus drive his/her further engagement in the development process.

In order to enable the implementation of such tutoring strategies, we have previously introduced a granular model of the Artificial Intelligence domain of knowledge in the paper called "*An ontology of knowledge components in the domain of Artificial Intelligence*" [24]. The ontology was used to build a corresponding knowledge graph using Neo4j – see Figure 2 below for a partial image of this knowledge graph (for exemplification purposes).

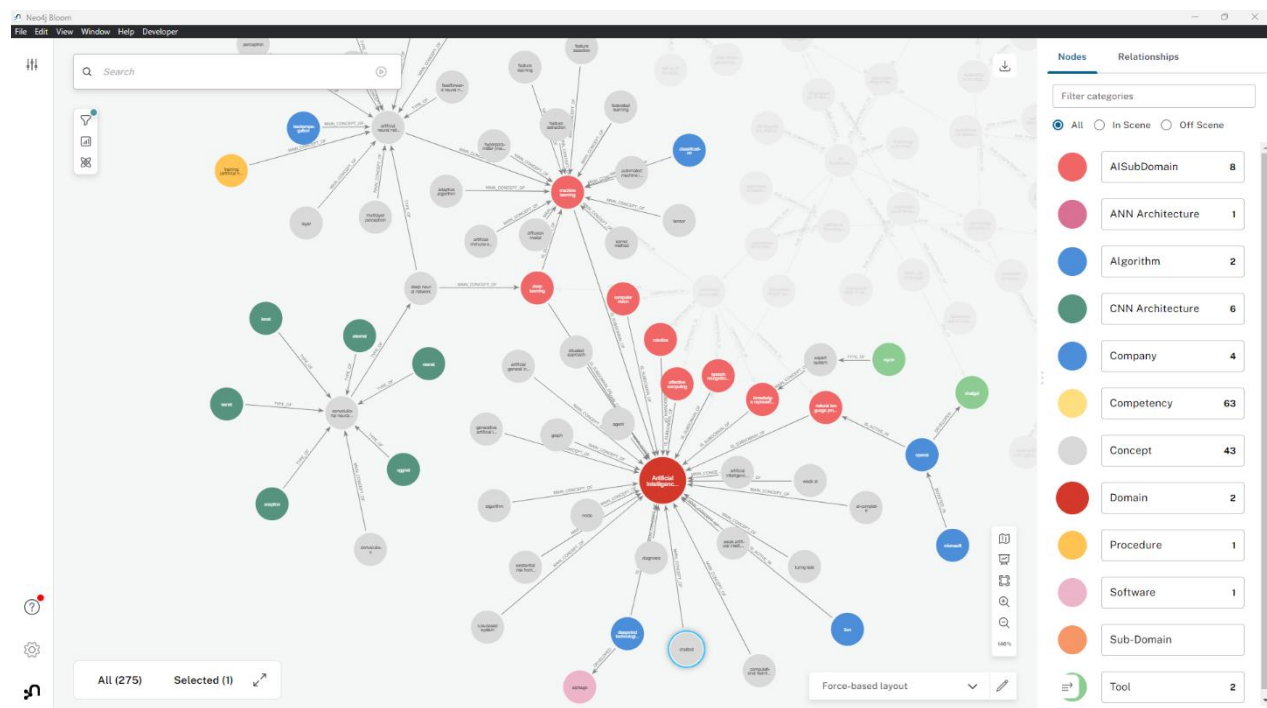


Figure 2: An ontology of knowledge components in the domain of Artificial Intelligence

Source: Authors' own contribution

(7) **Execute Tutoring Intervention:** A dedicated type of tutoring intervention will follow as per the decision of the *tutoring module*. This is the most appropriate action that addresses the specific, contextual need for development of knowledge, skills, attitudes and/or other competency dimensions of the manager.

(8) **Inner Loop Diagnosis:** following the collection of tutoring interventions in each of the development sessions (inner loops) a quick diagnosis of progress will take place. It can be a simple test of the new learned knowledge component or else conclusions and/or take aways from a case study, a self-reflection point or similar results.

(9) **Update Student Model:** according to the proficiency level achieved in each development session for the components of competency C_j , the student model that describes the particular profile of the manager is updated accordingly. As such, each new development session can start with the information describing the status each manager has reached so far, information that is stored in the application profile of the user/manager.

Particular attention is given in the scientific literature to the modeling of the forgetting curve, namely knowledge components that the manager forgets in time, if not used/applied in solving real life challenges (either in simulated, practice environments or at job, in role-specific activities).

(10) **Update the Manager's Metacognitive Level:** it is critical for the effectiveness of the process and the manager's engagement in long-term development journeys, to communicate to the manager - at least once in each session - a summary of his/her progress toward achieving the desired goals and objectives, and an estimate of the effort required to cover each specific competence in the targeted state.

Conclusion

In this paper we proposed an algorithm for the personalized development of managerial competencies in the domain of Artificial Intelligence. The successful implementation of such an algorithm is expected to accelerate the development of critical capabilities for managers today, regardless of their role, industry and domain/function they operate in.

While the concern for applying Artificial Intelligence in the processes of learning/education is not a new field of study, our work addresses a couple of novelty areas for scientific research:

- According to our knowledge there is no other AI competency framework designed to address the needs of business managers in the domain of Artificial Intelligence.
- Most of the successful/commercial ITSs developed to date have focused on educational fields more relevant for pupils and students: lower grades algebra and geometry, physics, programming languages, databases/SQL, etc. There is little to no research into developing intelligent tutoring systems targeted at adult education, even less ITSs targeted at business management professionals.
- Most of the knowledge tracing algorithms focus on identifying the knowledge state rather than identifying the state of competency components including skills, attitudes, and other relevant personal characteristics of a manager.

A known limitation of our work is the lack of a working prototype to test alternative models for diagnosis, tutoring strategies, and effectiveness of the end-to-end process. This shortcoming will be addressed in the next stage of our research by the development of a minimum viable product (MVP) that can host and test such components. We expect this MVP will allow the collection of significant information/data points for a statistical analysis of results.

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