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Social Alignment in Digital Transformation: A Case Study

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Abstract

Digital transformation necessitates cross-functional discipline and collaboration, making alignment between the information technology (IT) team and other business units crucial. Social alignment, which centers on interpersonal relationships, holds significant importance among the various alignments. Strong relationships between IT and non-IT employees foster a willingness to cooperate and engage with others, thereby serving as a foundational element for digital transformation. However, prior studies have primarily focused on strategic alignment, leaving limited research on social alignment throughout the entire digital transformation of an organization. In this study, we examined MyComputer, an international electronic manufacturing services company, to gain insights into the factors influencing social alignment during the transformation process. Drawing upon the theoretical perspective of social capital theory (SCT), our research findings demonstrate that relational, cognitive, and structural linkages exhibit mutual reinforcement and contribute to the enhancement of social alignment. Furthermore, we have identified structural linkages as the dominant influencer among the three types of linkages. In addition to this, organizational endeavors, including learning from past failure experiences, cultural reshaping, and visionary and delegating leadership styles, emerge as key factors in achieving social alignment.

Keywords: Digital transformation; Social alignment; Social capital theory; Business-IT alignment process

Chapter 1. Introduction

1.1 Background

In the past few decades, academia and practice have highlighted the importance of digital transformation because it not only reinvents companies, but it also changes markets and entire industries (Bharadwaj et al., 2013). However, the average digital transformation failure rate is stunningly high, at 87.5% over the past few years (Wade & Shan, 2020). In addition, McKinsey & Company (2018) conducted a global survey and found that the success rate in industries known for their digital expertise, including high tech, media, and telecommunications, does not exceed 26%.

From these studies, there are numerous challenges, and we do not know much about digital transformation. Studies show that cross-functional collaboration and alignment between each business unit are essential elements of digital transformation, which aims to fuse together organizational and information systems (IS) strategies (Schlosser et al., 2015; Vial, 2021). Benbya and McKelvey (2006, p. 294) conceptualized IS alignment as "a function of coevolutionary dynamics" that can potentially lead to better organizational performance. IS alignment includes continual interactions and adjustments across different dimensions (e.g., strategic, operational, and social) and three levels (e.g., individual, business and IS group, and strategy) (Benbya et al., 2019). As an increasing number of people study this topic, researchers have gradually converged on three main dimensions: strategic/intellectual alignment, social alignment, and operational alignment (Chan & Reich, 2007). These three dimensions have proven to be highly relevant to the success of organizations. Strategic alignment is, overall, the most frequently studied among all the dimensions (e.g., Coltman et al., 2015; Fischer et al., 2020); it emphasizes how to align IS strategy with business plans, goals, and missions to impact organizational performance (Wu et al., 2015). However, Benbya et al. (2019) conducted a research curation on IS alignment research published in *MIS Quarterly* from the journal's inception through November 2018, finding that several issues of strategic alignment research have been critiqued. First, scholars have discovered that IS and business strategy are bidirectional and coevolving, not just conforming unidirectionally to business strategy. In addition, IS alignment is not a "static outcome" but a "dynamic emergent process." Second, researchers need to pay more attention to how to realize the IS strategy instead of viewing it as a plan. As studies have moved from intended strategy to actual practices, an increasing amount of research has aimed at other dimensions to take the complexity of IS alignment into account (e.g., Preston & Karahanna, 2009; Reich & Benbasat, 2000; Wu et al., 2015).

1.2 Research Objective

Considering the rapid pace and scale of change in both the business and technological environments, Llamzon et al. (2022) suggested that we should place less of an emphasis on the strategic dimension of IS alignment, instead concentrating more on the operational and social factors. Social alignment has not only received increasing attention over the past 20 years, but it has also built the basis for other dimensions of alignment (Schlosser et al., 2015). Social alignment focuses on possessing comprehension and dedication toward the mission, objectives, and plans of both business and information technology (IT) executives (Reich & Benbasat, 2000). To derive greater strategic use from IS (strategic alignment), a common understanding is an important prerequisite, particularly in the context of digital transformation, which relies heavily on cross-organizational and cross-departmental collaboration. The CIO needs to understand current business goals to align the organizational IS strategy with them, and the top management team (TMT) needs to explain their strategy to the CIO. Moreover, at the operational level, IT and other business departments need to collaborate and foster cross-domain interconnectedness to achieve organizational goals (Wagner et al., 2014). As a result, some departments, workshops, or other infrastructures (operational alignment) have been set up to facilitate an understanding among business units and IT (Preston & Karahanna, 2009). Previous research has focused more on the effects of the working relationship between the CIO and TMT (e.g., Preston & Karahanna, 2009), which is a horizontal dimension in the organization. These studies also examined how social alignment influences business outcomes (Liang et al., 2017; Wu et al., 2015). However, a successful digital transformation relies not only on social alignment at the management level (Schlosser et al., 2015), but also on the process of achieving alignment among staff (Pelletier et al., 2021). Hence, the present study focuses on the relationship between every business unit and IT, including high-level executives and operational levels, to provide a comprehensive perspective of social alignment in digital transformation. Our research question is as follows:

RQ: What factors affect social alignment in digital transformation?

We chose MyComputer, a global manufacturing firm in Taiwan, as our case study. MyComputer has been a trailblazer in designing and manufacturing its own-brand rackmount systems, tower servers, and PC chassis for over 35 years. In the past, it launched its first digital transformation, which was also a process optimization project. Since the people involved were only part of a certain section of the process and had some conflicts with the consultants, the project failed. Several years later, with increasing internal pain points and the threat of external competitors, the company implemented a second digital transformation. Reich and Benbasat (2000) highlighted the company's background and its IT history as the key factors affecting alignment. From this point of view, it is very suitable to explore what changes this firm has made to achieve social alignment, which, in turn, has led to the success of digital transformation. Moreover, because it was a digital transformation project for the whole organization, foreign branches and manufacturing plants were required to join the project. We can take advantage of this feature to gather more comprehensive information and views to examine the interface among business units in our study. In conclusion, although digital transformation in the manufacturing industry has been studied from diverse perspectives, such as exploring the driving factors for digital transformation in companies of different natures (Liere-Netheler et al., 2018) and investigating barriers to digital transformation (Vogelsang et al., 2019), there is still a gap in discussing social alignment, one of the important factors for the success of digital transformation (Pelletier et al., 2021; Schlosser et al., 2015), from a broad viewpoint. The overall research goal was to (1) investigate the different organizational factors that influence social alignment in digital transformation and (2) explore social alignment in the horizontal and vertical dimensions.

To observe and analyze the relationships between departments throughout the company (including operational level, high-level executives, and formal or informal connections), we used social capital theory (SCT) as our theoretical foundation. Social capital contains the "actual and potential" available resources from the relationship network (Nahapiet & Ghoshal, 1998). At the directorial level, managerial social capital is made up of "formal and informal relationships that managers have with others" (Helfat & Martin, 2015, p. 1286). Managerial social capital can help managers access different types of information and support, allowing them to create a business understanding of IT, identify market opportunities, and overcome challenges (Li et al., 2018). Hence, within certain limits, the denser social capital a company has, the more advantages it will have in building and sharing intellectual property in the market (Nahapiet & Ghoshal, 1998). At the operational level, Wagner et al. (2014) found that social capital can help IT staff establish their business understanding. As the relationship between each business unit grows, social capital accelerates knowledge exchange, resulting in shared understanding. As discussed above, social capital is an important resource to achieve social alignment (Kearns & Sabherwal, 2006) and is an essential element in the organization, including mutual trust, shared language, and other factors that can affect the relationship (Rezaei et al., 2020). We have adopted SCT as our theoretical lens so that we can observe the relationships in the whole company and understand the basic structure of social alignment. By leveraging its structural, cognitive, and relational components, we have specifically examined and explained how it influences the social dimensions of the alignment of the company. After interviewing some operational staff and executives in line with SCT, we found that formal and informal teamwork or strong relationships in the working environment are also the keys to social alignment. In addition, we also developed a model that interprets the interrelationship among the company's background, shared domain knowledge, shared understanding, and social capital (Reich & Benbasat, 2000). The results can help practitioners understand the essential conditions for aligning the business goal with the organization while also suggesting that IT and each business unit focus on their working relationships beyond the short-term goals of the team.

In the present paper, we first introduce the theoretical framework and research methodology used. We then move on to the analysis of the results in the third section, while the fourth section summarizes the main findings. Finally, in the last section, we discuss the implications of the findings and provide some advice for both academia and practice.

Chapter 2. Literature Review

2.1 Digital Transformation

Scholars have examined the various perspectives and crucial aspects of digital transformation in the literature for many years, including the definition, internal or external factors, and phases of digital transformation (e.g., Dimock, 2019; Gurbaxani & Dunkle, 2019; Mergel et al., 2019). Broadly speaking, digital transformation involves the use of new enabling IT/IS solutions and trends to make business improvements (Heilig et al., 2017; Liere-Netheler et al., 2018). Moreover, digital transformation serves as a distinctive backdrop for business process reengineering (BPR). This is because adapting to new digital technologies as part of digital transformation prompts a reevaluation and restructuring of business models and processes (Baiyere et al., 2020). A study in the financial industry summarized digital transformation as “the use of technology (including social, mobile, and emerging technologies) to radically improve the performance or reach of enterprises” (Karagiannaki et al., 2017, p. 2). Digital transformation relies on innovation; accordingly, previous research has also defined it as the company’s reinvention, including its vision and strategy, organization structure, processes, capabilities, and culture (Gurbaxani & Dunkle, 2019). To sum up, digital transformation is concerned with leveraging digital technologies (such as social media platforms, mobile devices, data analytics tools, or embedded systems) and developing a digital business strategy to improve business performance or organizational process rethinking (Eden et al., 2019; Horlacher et al., 2016). The digital business strategy is not only related to firms and supply chains, but also to dynamic ecosystems (alliances, partnerships, and competitors) (Bharadwaj et al., 2013). Consequently, different functions have to work together and do many complex tasks interdependently to reach a consensus and set goals (Horlacher, 2016). Li et al. (2018) believed the alignment between IT and business is essential because the senior executive team needs to understand digital technology capabilities clearly and how these capabilities support business objectives. For this reason, the chief digital officer (CDO) has been an emerging positions that an increasing number of companies are creating to support digital transformation activities (Tumbas et al., 2018). CDOs have the authority to ensure their TMT participation and commitment while enabling horizontal and vertical alignment (Horlacher et al., 2016). Without alignment, there will be conflict and misunderstanding among groups, and project management will be more ineffective and inefficient (Burton-Jones et al., 2020). Misalignment obstructs the success and attainment of a company's technological, industrial, and strategic goals (Pelletier et al., 2021). Nevertheless, the research on the precise mechanisms and processes of achieving IT alignment is still limited, including different units, levels, and multibusiness organizations (e.g., Burton-Jones et al., 2020; Liang et al., 2017; Pelletier et al., 2021; Reynolds & Yetton, 2015).

2.2 Social Alignment

Successful digital transformation heavily relies on achieving alignment between business and IT, making it a crucial and vital element (Burton-Jones et al., 2020; Liang et al., 2017; Wagner et al., 2014). Alignment can be further classified into three categories: strategic/intellectual alignment, operational alignment, and social alignment (Chan & Reich, 2007). Although strategic alignment has been the most popular research topic in all dimensions, previous research has mostly focused on the static outcomes (e.g., financial and business performance) (Benbya et al., 2019; Pelletier et al., 2021). However, digital transformation is a dynamic process that requires "combinations of information, computing, communication, and connectivity technologies" (Vial, 2021, p. 137), and the process of developing IS and business strategy is two-way and collaborative one (Bharadwaj et al., 2013). Hence, greater attention has been given to social alignment, which emphasizes the relationships and common understanding among the CIO, TMT, and staff (Schlosser et al., 2015). Social alignment has also been recognized as the most critical prerequisite for digital transformation (Preston & Karahanna, 2009). Our definition of social alignment is related to strategic IT alignment from a social perspective. It is the alignment between business and IT with a "shared vision for IT" and an "understanding of current objectives" (Reich & Benbasat, 2000, p. 81). In the beginning, the research on this topic focused on relationships between executives (e.g., Kearns & Sabherwal, 2006). Later on, the informal relations between business units and IT staff in the organization were studied (Ghosh & Scott, 2009). Hence, social alignment, also known as relational alignment, refers to formal and informal teamwork, communication, and connection through informal organizational structures and working relationships (Preston & Karahanna, 2009). To achieve social alignment, Burton-Jones et al. (2020) divided the process into four phases: connection, respect, cross-disciplinary participation, and social alignment. If each group or individual can learn from others, they can connect and show respect, which provides the foundation for cross-disciplinary participation, finally reaching the goal of social alignment.

From the aspect of business direction, some researchers have found that social alignment can be separated into long and short term. Short-term social alignment is defined as the shared understanding of short-term (one- to two-year) plans and goals, whereas long-term alignment refers to the shared understanding of common visions (Reich & Benbasat, 2000). The key factor in both types of alignments is *shared domain knowledge*, which refers to business managers who are knowledgeable in IT and IT managers who are knowledgeable in business (Reich & Benbasat, 2000). In addition, when it comes to *shared understanding*, some researchers have defined this as *an extension of social alignment* (Tan & Gallupe, 2006). Shared understanding is the level of shared cognition on the role of the IS between the CIO and TMT in the organization. Additionally, Preston and Karahanna (2009) discovered that the CIO and TMT can develop a shared understanding by sharing their *shared domain knowledge* of IS and how it can improve the organization's capabilities. In other words, to foster a shared understanding, it is important for the CIO to possess business knowledge and for the TMT to possess IS knowledge. This can enable them to engage in each other's critical processes, appreciate each other's contributions, and provide mutual support (Reich & Benbasat, 2000). Furthermore, they also explored some factors that lead to the development of shared understanding, for example, a shared language. To communicate and connect effectively, the CIO and TMT utilize a common language, enabling them to integrate knowledge, reach a consensus on situational perspectives, and foster a shared understanding within the organization (Johnson & Lederer, 2005; Preston & Karahanna, 2009). However, previous studies have been divided on how to achieve social alignment, with some focusing on the elements of the social alignment formation process, such as internal and external structures (Pelletier et al., 2021). Most discussions have focused on business performance and the impacts of alignment (Liang et al., 2017; Wu et al., 2015) because achieving social alignment for improved performance is the ultimate goal of businesses (Burton-Jones et al., 2020; Pelletier et al., 2021). Another gap is cross-functional collaboration, which is an important element of digital transformation (Liang et al., 2017). Not only is top-down alignment crucial, but bottom-up cooperation is also essential. Nevertheless, the research has mainly explored social alignment at a certain level of the firm. For example, Reich and Benbasat (2000) focused on the top management level, which is between management teams and IT executives. Chan (2008) explored the informal relations between IT staff and businesses, which are at the operational level.

2.3 Social Capital Theory

Although previous IS literature has found some antecedents of social alignment, such as shared domain knowledge, informal and formal connections between staff, and successful IT histories, it is still difficult for both business and IT to achieve social alignment (Schlosser et al., 2015). Identifying and deploying "IT resources and competencies as well as the relational capabilities" that can make digital strategies successful is a critical step in the social alignment process (Pelletier et al., 2021, p. 44). Because social alignment emphasizes the relations and connections between business and IT (Preston & Karahanna, 2009), we have used SCT as our theoretical lens to obtain a better understanding of the factors of social alignment. Karahanna and Preston (2013) proved that the integration and exchange of business and IT knowledge, which is a major prerequisite of social alignment, can be accelerated by social capital, and mutual trust between the CIO and TMT can be built by shared cognition. Social capital includes all types of resources, networks, and assets from the relationship network (Nahapiet & Ghoshal, 1998). This theory posits that social capital can be assessed and categorized into three dimensions: structural, cognitive, and relational (see Table 1). Recently, an increasing number of studies have used SCT to research social alignment in digital transformation and explain the relationship between different business units, especially at the operational level (Wagner et al., 2014).

The structural dimension of social capital is “the overall pattern of connections between actors” (Nahapiet & Ghoshal, 1998, p. 244). Wagner et al. (2014) described structural dimension of social capital as a method of communication and interaction among IT and non-IT employees, including formal and informal meetings. For instance, having meetings or doing projects together can help staff members consider the effect of their work from a higher-level perspective, exchange their knowledge, and enhance their willingness to collaborate with others. The cognitive component of social capital refers to the shared language and interpretations that exist among individuals or groups (Nahapiet & Ghoshal, 1998). It extends to the understanding of each other’s perspectives between IT and business units (Wagner et al., 2014). In other words, not only can IT explain the technical problem in business language to others, but it can also show if the business employee has background knowledge of IT. Other research has also indicated that sharing knowledge with each other is a way for IT and business executives to reach a consensus on strategies and monitor the trends, opportunities, and threats of the external environment easily (Tallon & Pinsonneault, 2011; Wu et al., 2015). Finally, the relational aspect of social capital is the particular relations that people have (Nahapiet & Ghoshal, 1998), including mutual trust and respect. With this dimension, business units trust IT and do not worry about the work that needs to be coordinated. Gilchrist et al. (2018) observed that, if groups learn knowledge from others, they begin to respect each other. Moreover, because they can gain opinions by joining cross-disciplinary activities, they are willing to hold discussions with other people. In conclusion, to reach the goal of social alignment, these three dimensions of social capital have strong relationships and mutually affect each other. For example, different parties in the organization need to trust others (relational dimension) (Burton-

Jones et al., 2020) and understand others' viewpoints (cognitive dimension) through workshops or meetings (structural dimension). In our study, we adopted SCT as our lens to observe the dynamic relationships and multistage processes of social alignment (Gilchrist et al., 2018). At the same time, we have taken more variables (e.g., past experience, personal knowledge bases, and personalities) into account to examine if they affect social capital in social alignment (Karahanna & Preston, 2013).

Table 1. *Previous Research Using SCT on Digital Transformation*

Author	Dimensions of social capital investigated	Methodology	Summary and findings
Van Den Hooff and De Winter (2011)	Relational, structural, and cognitive linkages	Interview and survey	• Social capital directly affects perceived IT performance and indirectly influences it through knowledge sharing. • The IT department emphasizes exchanging factual information, while the business organization values mutual relationships. • Higher levels of cognitive and relational social capital lead to mutual understanding and a positive perception of the IT department's performance by the business organization.
Wagner et al. (2014)	Relational, structural, and cognitive	Survey	• They examined the effects of relational, structural, and cognitive linkages of social capital on operational business–IT alignment.

	linkages		• The cognitive dimension (common language) has the strongest influence on social alignment. • The effect of the structural linkage is strongly mediated by cognitive and relational linkages.
Schlosser et al. (2015)	Relational, structural, and cognitive linkages	Survey	• They conceptualize social alignment as the combination of social capital between business and IT and IT personnel's business understanding. The former deals with structural, relational, and cognitive relationships. • Both formal and informal IT governance integration mechanisms have a positive effect on social capital, and social capital positively influences business performance.
Moon et al. (2018)	Relational, structural, and cognitive linkages	Survey	• Adopting a social capital theory perspective, they viewed social alignment as the social capital that exists between business and IT executives in which the outcome is integrated knowledge. • Relational leadership style facilitates structural, relational, and cognitive linkages, and these three linkages positively influence the exchange of integrated knowledge with business executives, leading to greater effectiveness of

			the information security system and improved organizational performance.
Chen et al. (2021)	It does not break down the dimension of social capital but rather treats it as a type of CIO/TMT partnership	Survey	• By directing the attention of top management to strategic IT issues, CIOs can influence the occurrence of digital innovation. • Four categories of organizational assets, including strategic decision-making authority, partnership with the top management team (TMT), IT-related strategic knowledge, and political savvy, are crucial for CIOs to become effective issue sellers.
Lyu et al. (2022)	Social structural capital, Social relational capital, and Social cognitive capital	Survey	• The study suggests that building social capital is crucial for digital firms to improve their innovation performance during the pandemic. • Cross-border knowledge search plays a vital role in mediating the relationship between social capital and innovation performance, along with absorptive capacity. However, the specific mediation effect varies across different dimensions of social capital.
Ji et al. (2022)	Entrepreneurs' technological social capital	Text mining	• The implementation of technology-driven digital transformation (TDT) has a favorable impact on financial performance (FP), whereas

	(ETSC), entrepreneurs' business social capital (EBSC), and entrepreneurs' institutional social capital (EISC).		market-driven digital transformation (MDT) exhibits a delayed but positive influence on FP. • ETSC strengthens the relationship between MDT and FP in a positive manner, while EBSC enhances the relationship between both TDT and MDT with FP.
Heubeck (2023)	Social structural capital, social relational capital, and social cognitive capital	Survey	• Shifting the research focus from the level of firms to individual managers through the perspective of the dynamic managerial capabilities theory. • Managerial social capital (including structural, relational, and cognitive social capital) acts as a moderator in the relationship between leadership skills and digital business model transformation (DBMT), amplifying the indirect impact of leadership skills on firm performance through DBMT.

Chapter 3. Research Method

3.1 Case Description

We conducted an in-depth case study at an international company called MyComputer, which has about 2,000 employees and an average monthly revenue of $700 million in the electronic manufacturing services (EMS) industry. It has been devoted to designing and manufacturing its own-brand rackmount systems, tower servers, and PC chassis for over 35 years. In this period, it also received awards such as the iF Design Award and the Computex Best Choice Award. MyComputer is a special case because of certain characteristics. First, the digital transformation in this company was carried out within the conglomerate, including other companies and factories abroad (Appendix 1). We can study and observe the interactions and relationships from a more comprehensive viewpoint and take more potential variables into account. Second, MyComputer is an exemplary enterprise because it has been continuously investing in technologies and delivering the most credible server and PC chassis with the highest innovative standards. To improve its competitiveness, it has conducted some digital transformation projects to upgrade and renew its business model, working process, products, and services. In light of the fact that a positive IT history is a precursor to alignment (Reich & Benbasat, 2000), we examine how the company's past track record and the individual's knowledge base affect alignment (Karahanna & Preston, 2013).

The goal of this transformation is to optimize the overall process during the upgrade and integration of internal systems. After the adoption of the new system, the working efficiency and business results could be improved, which could even change the cooperation model with upstream and downstream vendors or lead to the development of new business models. With past failures, MyComputer knew it was necessary to find experts who were experienced in transformation and familiar with the system to support the project. Therefore, they worked with the original system consultants instead of experts from other IT consulting firms. This project was divided into three stages. First, in the planning proposal stage, the TMT and external consultants discussed who would be involved in the project and timeline. They also needed to ensure that the plan was aligned with the company's objectives. Second, they spent about four months in the design phase, during which we were involved in the project discussions. In this period, the consultants verified that the requirements and processes proposed by each department were compatible with the system architecture, while the company's departmental representatives and supervisors had to repeatedly and internally confirm that the process modifications matched the actual operational processes. This phase was an important foundation for the entire project because smooth system integration requires process optimization and an ideal architecture for main IT services (Goerzig & Bauernhansl, 2018). They spent their efforts on data digitization, integration of process pain points, and cross-functional discussion of solutions. Finally, in the system integration stage, they followed the results that they had discussed before launching the customized system. This took the most time to make all the employees of the group (including headquarters, overseas branches, and factories) understand how to use the system. From user training to system testing to system release, the system was continuously modified until it was successfully and smoothly used and achieved the desired goals.

3.2 Data Collection

To address the research question, we adopted an inductive qualitative research methodology. Social alignment is a complex phenomenon because it occurs across different functions and management levels. As a result, we not only participated in their company's meetings for four months, but we also explored this topic by interviewing staff who were engaged in the digital project. Initially, we observed and recorded the data (attendees' behaviors, interactions, and meeting materials) from the digitalization meetings and workshops. We chatted with operational employees to understand their views on the digital transformation project. After collecting, analyzing, and interpreting observational and archival data, we conducted six semistructured interviews and designed our interview guides (Appendix 4) for different interviewees to obtain a more diverse and complete viewpoint. This helped us become more familiar with the digital transformation process from the perspective of practitioners and confirmed that social alignment was playing a key role. The adaptability of semistructured interviews made them an appropriate method for investigating complex or sensitive issues, and researchers can tailor the interview schedule to align with the professional, educational, and personal histories of the study participants (Barriball & While, 1993). Finally, we collected substantial data through three methods (see Table 2): interviews, participant observation, and archival data. In particular, we conducted six semistructured interviews with different levels of MyComputer staff (see Table 3). First, we interviewed the CIO, who was also the leader of the digital transformation project, and then, we interviewed employees in the areas of IT, inventory management, research and development (R&D), and finance. All interviews were recorded, and an 83-page transcript was generated.

The data analysis was a three-step and iterative process (Strauss & Corbin, 1998) to derive the framework of social alignment. First, we used SCT as our theoretical lens to discover and categorize the properties through open coding (Strauss & Corbin, 1998). We sought to identify each type of relationship: formal and informal communication, enabling connection and interaction in meetings and workshops. Second, because the appearing concepts were discussed repeatedly with textual evidence and relevant literature, we based our analysis on the principle of axial coding proposed by Strauss and Corbin (1998). The coding process for this stage involved finding the correlation and causality between those concepts. It focused on how concepts crosscut and link, thus generating subcategories and making the concept more convincing. We referred to Huang et al. (2017), who used tree diagrams to present the analysis results. Based on each category, we generated different tree diagrams, as shown later in Figures 1, 2, and 3. In these figures, we have highlighted the interview transcript marked in the previous step on the left side, and on the right side, we put the axis. Finally, we carried out selective coding (Strauss & Corbin, 1998) to figure out and explain how social capital and other elements interplay in the process of fulfilling social alignment in digital transformation.

Table 2. *Data Collection*

Interviews	6 interviews (mean length: 62 minutes) with 9 respondents generated 56315 words in Mandarin
Participant observation	8 occasions (mean length: 174 minutes), including 4 meetings with consultants for all departments, 1 group meeting, and 3 department meetings with consultants (see **Appendix 2**)
Archival data	Project descriptions, presentation materials, meeting minutes, and flow charts (see **Appendix 3**)

Table 3. *Interview Data*

Date	Time	Method	Interviewee	Number
2021/12/10	14:00–14:30	Face-to-face	CIO	1
2021/12/27	15:00–16:00	Online	CIO	1
2022/10/03	09:00–10:00	Online	IT (Project manager)	2
2022/10/03	10:30–11:45	Online	1 project leader in the inventory department	3
2022/10/24	09:00–10:10	Online	1 project leader and 1 project member in the R&D department	4 and 5
2022/10/24	10:30–11:47	Online	1 project leader and 3 project members in the finance department	6–9

Chapter 4. Case Analysis

After four months of actual participation in the transformation project, the collected data (see Table 2) were analyzed through the theoretical lens of SCT. We have summarized three factors that influenced each other and may have helped the stakeholders of this project achieve social alignment, which, in turn, positively impacted the process of digital transformation.

4.1 Relational Linkage

Our data analysis showed that the abstract assets of MyComputer not only allowed the company to integrate input from various departments more smoothly but even allowed cross-departmental members to discuss solutions together. We refer to the assets as *relational linkage*. Relational linkage describes *the perception of support, mutual trust,* and *mutual understanding* (see Figure 1). Before the project started, the consultant and executives would discuss and select the right people (seed members and process owners) from the various departments involved in the project. Individuals were chosen because of their strong communication skills and related backgrounds. These roles were very important because they bridged the gap between departments. This relationship between people and each other could improve communication and reduce misunderstandings. As described by the IT project manager:

> *The role of the flow owner is quite important. He must know what the internal problems are and then illustrate these problems clearly to the consultants. After the consultants proposed the solution plan, he came back to speak clearly with the internal people … This role must coordinate between and within processes (departments), so communication skills are*

very important. In fact, many of our teams have to rely on this role to do many things.

First, the *perception of support* helped the employees at the operational level feel valued. Perception of support referred to the support that employees received from the top, which helped motivate them. With the reward mechanism established by the management level, the staff not only received spiritual support, but also had substantial incentives to keep the project going. The second dimension is *mutual trust*. The company's senior management believed in the competence of the project members, and the communication between them was regular and transparent. In addition, the selected project members all had professional backgrounds in their respective departments; hence, questions could be answered through discussions, which increased their willingness to participate in meetings and workshops. As MyComputer's finance manager explained:

A lot of issues will run out at the beginning, and then, we will discuss them through meetings. Because we need some experts, you can see that financial accounting, business management, and cost (colleagues) are all involved in (the meetings). We also find accountants get together to discuss business management costs; that is, we all work together. We also have a financial advisor to help us. Because he has a wealth of experience, he can give us some direction.

The third dimension is *mutual understanding.* If colleagues can put themselves in each other's shoes, they can help each other when they encounter difficulties during the project. On the other hand, as long as the managers understand the context, they can flexibly deploy members when the project progress is stagnant. By understanding the pain points of the operational working process, high-level management teams can also propose corresponding strategies and reward mechanisms.

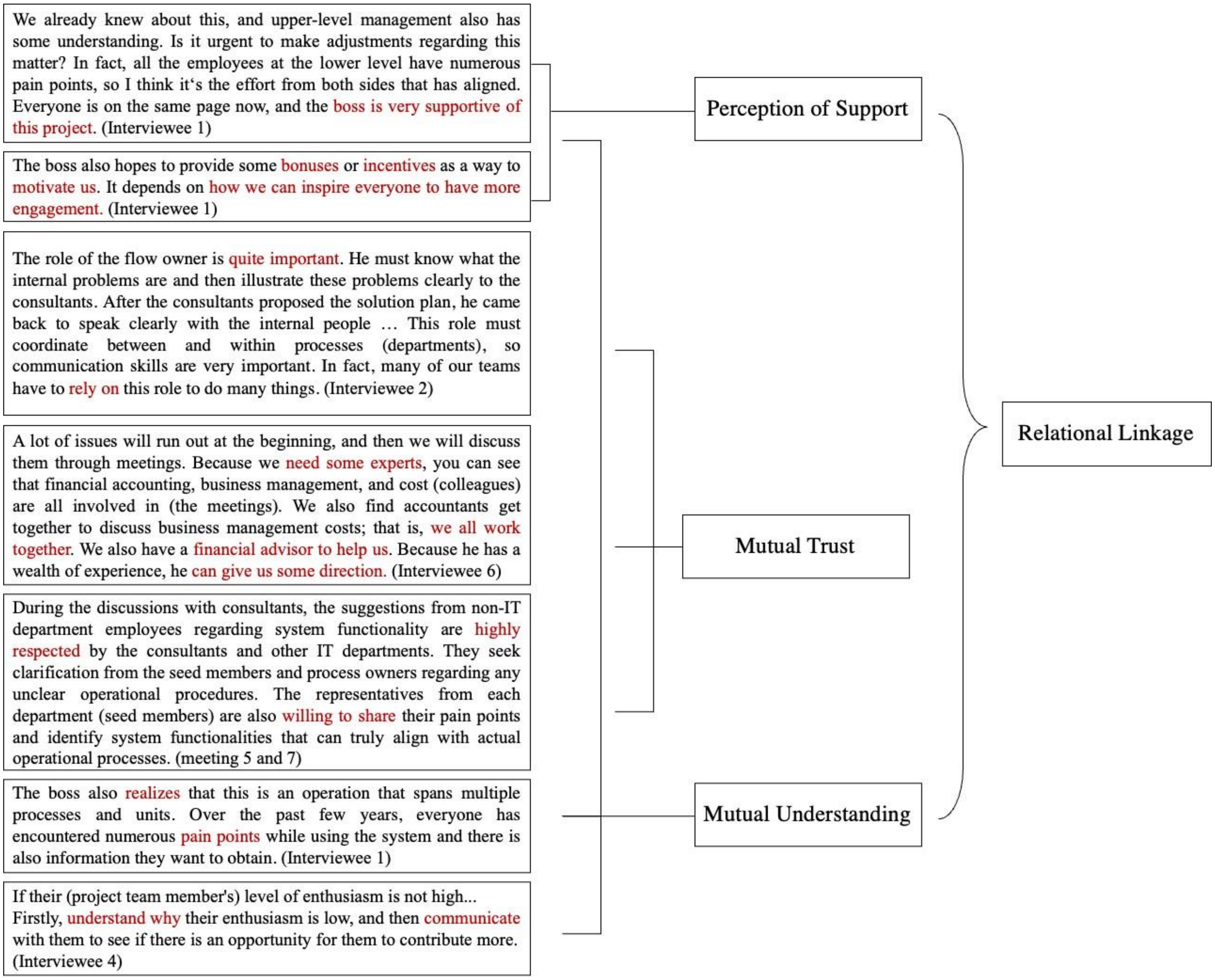


Figure 1. *The Dimension of Relation Linkage*

4.2 Cognitive Linkage

Our data analysis has revealed that communicating in shared languages to reach shared understandings between IT and business units was necessary for MyComputer. We refer to this cognitive connection as a *cognitive linkage* to denote the involvement in knowing, learning, and understanding things. We identified four key components of *cognitive linkage*: *attention to the process of things, cross-functional consensus, context focused,* and *IT-facilitated shared understanding* (see Figure 2). On this, the CIO said the following:

> *Instead of telling them what kind of data they need to produce, we will do our best to give the user a chance to understand what he needs to produce. To be honest, in this part, in addition to the meeting, we actually have to spend time communicating with the user.*

Understandably, in this context, reaching consensus among different departments and levels of the company was key.

First, *attention to the process of things* highlights that the process of achieving social alignment is iterative. Entry-level employees knew the operational process the best. As a result, at the beginning of the discussion, the management prioritized the general agreement of the staff. For upstream and downstream departments to agree on a proposal, all of them had to first understand the overall process and realize why it needed to be adjusted. This process of thinking was gradual and iterative because it was impossible to achieve a common understanding in a single meeting. When conflicts occurred, management would determine which option could achieve the company's objectives and expected benefits before then returning it to the staff to continue the discussion. Second, *cross-functional* *consensus* can be divided into vertical (management and staff) and horizontal (staff across units or executives and external consultants) alignments. This refers to a consensus on "future" goals, such as standard operating procedures (SOP) for future operational processes, the timeline and the members of future projects, and even expectation management. This alignment of objectives allowed the projects to run more smoothly. MyComputer's R&D manager mentioned the following:

> *In fact, we've received information about this project many times, so everyone is supposed to have a certain understanding of it ... The management thinks that if a digital transformation can achieve benefits externally, then we also think that we can improve all the internal processes and increase efficiency, so why not?*

The third dimension is *context focused*, capturing a consensus on "existing" pain points. For example, different units could understand the obstacles or current needs of each other's operational processes and work together to produce a holistic solution. MyComputer's finance manager described this as follows:

> *(In the same problem) maybe the solutions of the business department and the financial department will be different. Therefore, you will spend a lot of time on this difference ... We have been putting forward our own viewpoints and even drawing them out ... (After understanding) the sales team will come back to consider whether you can change the trading pattern or not. Maybe we can change our original one to a new one, and then, we will come up with a common solution together.*

The last dimension is *IT-facilitated shared understanding*, which means that IT staff use a common language to communicate with non-IT departments. IT staff members were not the leaders in this project, but rather, they were the facilitators. They needed to connect consultants and business units, especially where IT terminology would be used. After the business units proposed the direction of the revision of the operation process, IT assisted them in collecting data from a technical point of view and gave advice on whether it could be achieved or whether there was a need for adjustment. Finally, the feasibility of the system architecture was confirmed by external consultants only after a consensus had been reached within the company and the related data were prepared.

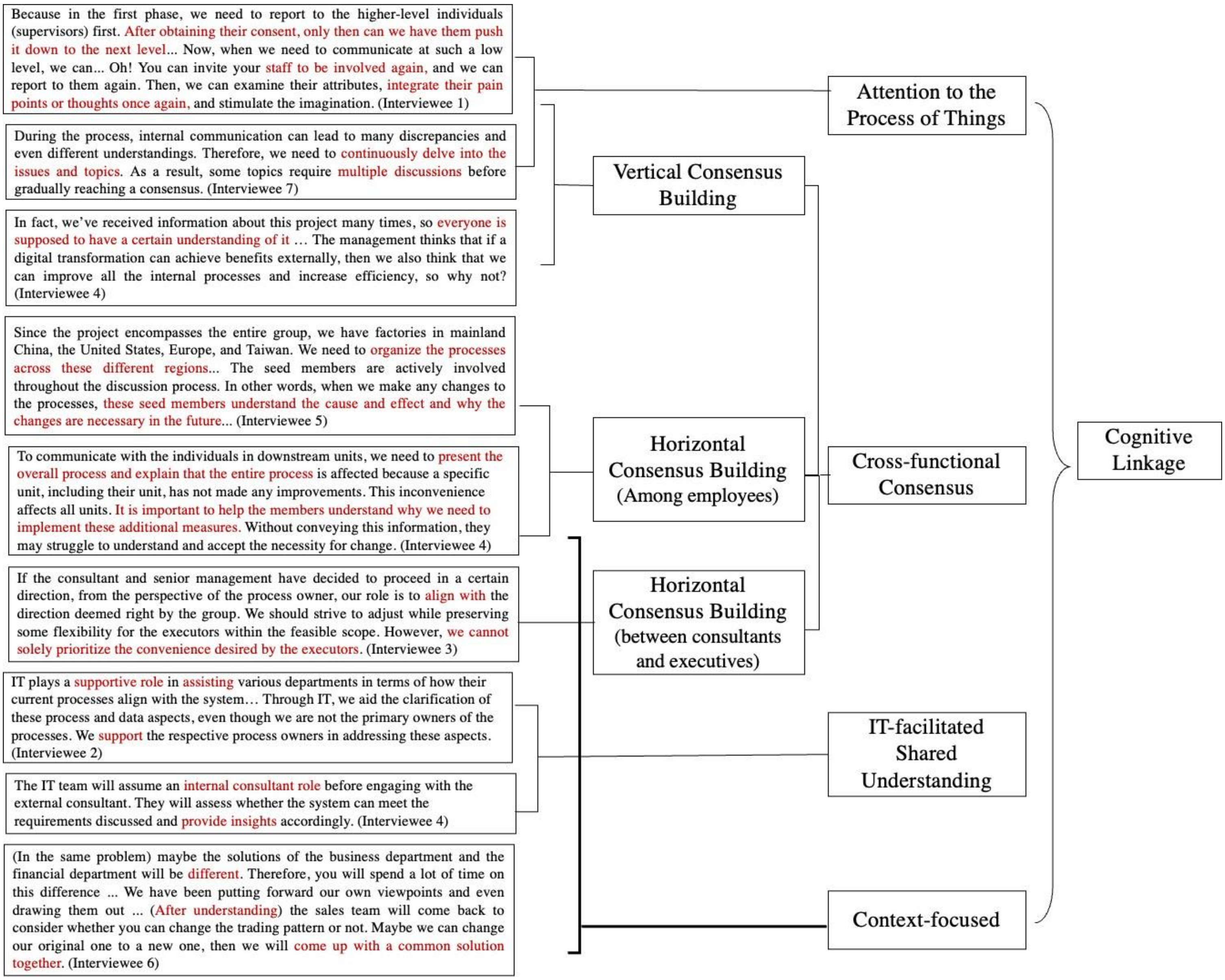


Figure 2. *The Dimension of Cognitive Linkage*

4.3 Structural Linkage

Our data analysis revealed another interesting factor: how effectively and efficiently MyComputer changed its structure to respond to the rapid changes required by this project. We refer to this connection and communication between employees as a *structural linkage*, as elaborated in Figure 3, which we have categorized into four dimensions: *shared project management system*, *self-directed learning*, *team-based organization*, and *IT organization restructuring*. Compared with relational linkage and cognitive linkage, this factor depicts more specific interactions within the company and even organizational restructuring.

First, a *shared project management system* involves meetings, workshops, training courses, or other official activities led by the company to exchange ideas more effectively. Staff from different departments have their own expertise, and through these events, they can learn from others and create win-win situations together. For instance, in this project, although IT staff were the facilitators, they also needed to absorb the background knowledge of each business unit to thoroughly understand their needs. The CIO shared the following:

> *We all want to have this kind of benchmarking data for each place according to the different products produced in each place, so that's why our IT staff have gone to a lot of these different department classes.*

Second, *self-directed learning* means that, in addition to mandatory events hosted by the company, employees also deliberated on some special topics through voluntary interactions and exchanges. By participating in the meetings, the employees could learn which departments were involved in the upstream and downstream of the workflow and with whom they could discuss it. In other words, some issues that have been delayed in meetings could be expedited by additional communication. Third, *team-based organization* represents a dynamic organization with a high degree of flexibility formed on an ad hoc basis for this project, in which professionals were temporarily drawn from senior management and the operational level across departments and branches (see Figure 4). Senior executives formed a “change team” to ensure project development was in line with MyComputer’s direction. The link between the company and the external consultants relied on the project management office (PMO), which was composed of the group project manager (PM) and external consultant PM. The PMO was responsible for setting project timelines, assisting departments with data collection, and defining key criteria. Taking into account that employees had their original work to complete while ensuring that all employees were able to solve their usual workflow problems and gain a practical understanding of the new system, each department and branch selected members to participate in the project as seed members and process owners. because of their domain knowledge and industry experience, flow owners represented the department to gather internal departmental issues and discuss them with other departments and consultants. After the discussion, the seed members and flow owners could pass on the system architecture proposed by the consultant to their colleagues within the department. MyComputer’s R&D manager said the following:

> *Because overseas factories and other branches abroad are involved in this project, the scope is so large that we need to divide them into many regional processes to organize them. The flow owners in charge are mainly responsible for syncing up with their partners to make sure that they’re on the same page. ... The seed members have been involved in the whole*

process of discussion. That is to say, if we want to change any process, those seed members know the cause and effect; hence, they can go back to their functions to hand over.

Fourth, *IT organization restructuring* describes MyComputer's deployment of IT resources, including adjusting IT department responsibilities and deploying IT staff to different business units according to their expertise (e.g., financial, manufacturing, and inventory-related knowledge) so that each non-IT staff member could combine their business knowledge with the technical capabilities of the IT department, ultimately leading to a smooth design of system architecture consistent with operational processes.

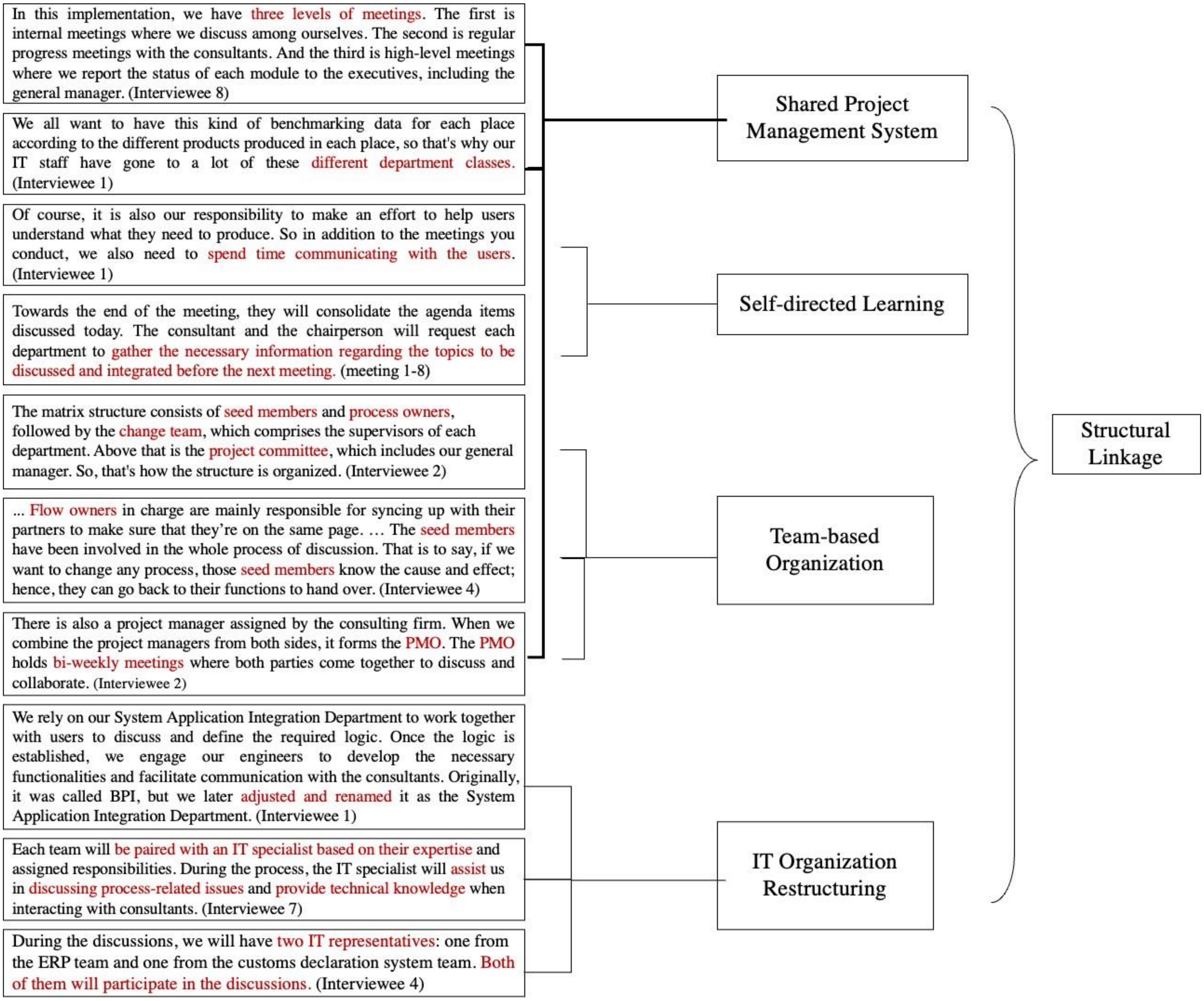
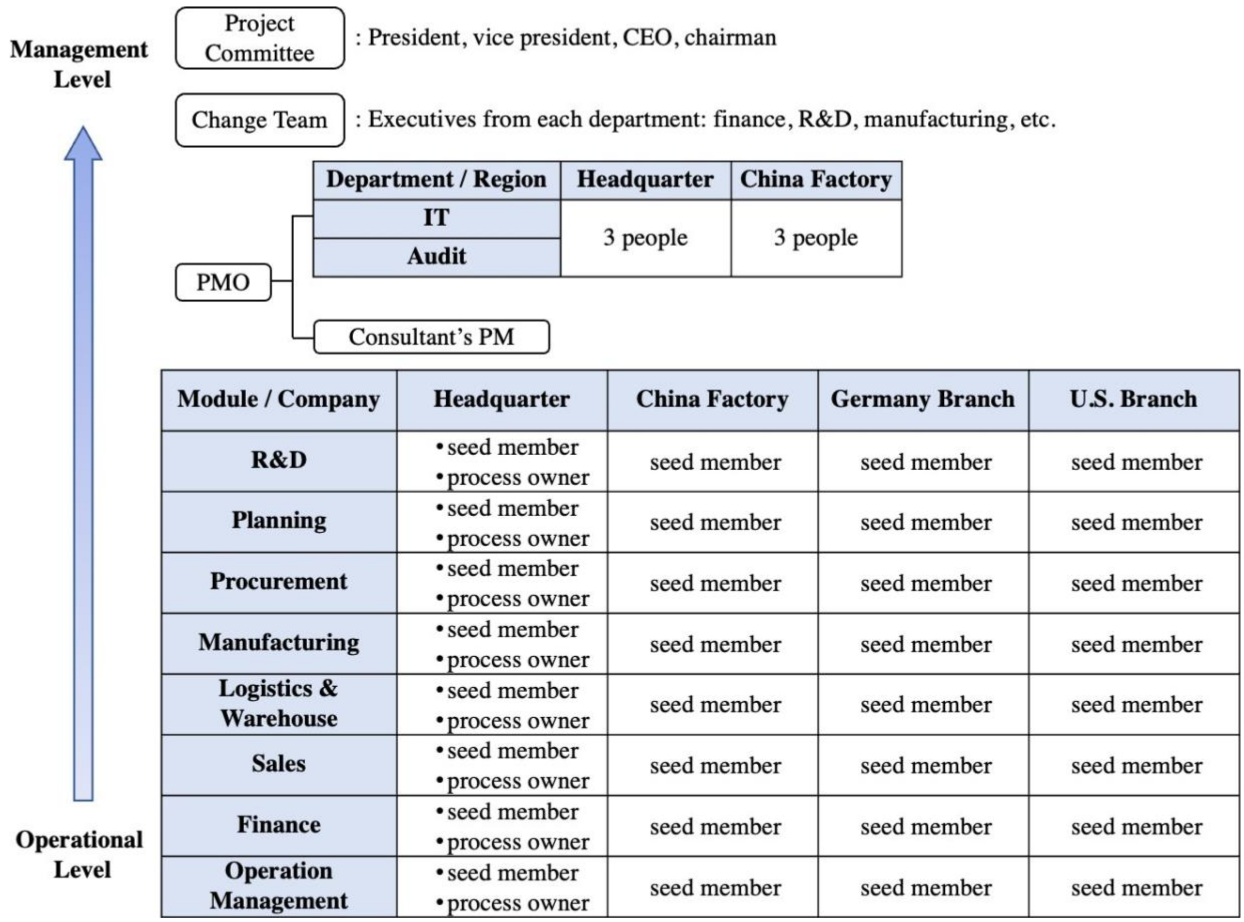


Figure 3. *The Dimension of Structure Linkage*



Department / Region	Headquarter	China Factory
IT	3 people	3 people
Audit		

Module / Company	Headquarter	China Factory	Germany Branch	U.S. Branch
R&D	• seed member • process owner	seed member	seed member	seed member
Planning	• seed member • process owner	seed member	seed member	seed member
Procurement	• seed member • process owner	seed member	seed member	seed member
Manufacturing	• seed member • process owner	seed member	seed member	seed member
Logistics & Warehouse	• seed member • process owner	seed member	seed member	seed member
Sales	• seed member • process owner	seed member	seed member	seed member
Finance	• seed member • process owner	seed member	seed member	seed member
Operation Management	• seed member • process owner	seed member	seed member	seed member

Figure 4. *Team-Based Organizational Structure*

Chapter 5. Discussion

Given the results, this case has illustrated how a small- and medium-sized enterprise achieved social alignment through a series of practices. In Figure 5, we provide a substantive look at the factors of achieving social alignment that drove MyComputer to realize successful digital transformation.

Companies can enhance their performance during digital transformation by utilizing social capital to facilitate cross-border knowledge acquisition, develop absorptive capacity, and assimilate external resources (Ji et al., 2022; Lyu et al., 2022; Metz et al., 2022). In this respect, most social capital studies have highlighted the importance of social capital in digital transformation or the inner relation of its different dimensions (e.g., Nuryanto et al., 2020; Schlosser et al., 2015; Wagner et al., 2014). However, in our research, the data analysis has indicated that structural linkage played a dominant role in leading the other two linkages to ensure the successful attainment of social alignment for digital transformation. By allocating IT resources and restructuring the organization, the structural linkage can foster relational linkage in terms of mutual trust and understanding (Gilchrist et al., 2018). The structural linkages also help engage staff members in cross-group discussions, enabling them to acquire more knowledge about the transformation project and gain insights from other domains, thereby reinforcing cognitive linkage. The enhanced cognitive linkages, in turn, reinforce relational linkage since it increased staff members' willingness to participate and fostered mutual respect (Hartl & Hess, 2017; Zahoor et al., 2021). By joining these meetings, staff members gain a better understanding of each other's challenges and collaborate on finding solutions. Simultaneously, they can reach a consensus more swiftly because of the presence of empathy and mutual trust among them

(Florek-Paszkowska et al., 2021). With these three connections in place, the alignment between business and IT toward the current business goals and IT vision can be strengthened more smoothly. In the words of MyComputer's Inventory Manager, "The individuals participating in the project must be identified and approved by the supervisor, ensuring that the supervisor is aware of their respective workloads within the project. Additionally, the person responsible for each process must regularly provide reports to the supervisor, allowing both the supervisor and senior management to effectively oversee the project and maintain certain expectations." Drawing from the aforementioned arguments, we provide the following first proposition:

- *Proposition 1: Although the relationship among relational linkage, cognitive linkage, and structural linkage is mutually reinforcing, structural linkage plays a dominant role in leading the other two linkages to ensure the successful attainment of social alignment for digital transformation.*

Our research has identified additional crucial factors in interaction with social capital. Drawing from the lessons learned from past system implementation failures, MyComputer recognized the necessity of seeking assistance from the system manufacturer's technical consultants. These consultants possessed extensive industry knowledge and a deep understanding of system functionality and technology, further strengthening MyComputer employees' trust in their expertise. The consultants played a pivotal role in bridging the gap between business units, narrowing the divide between business and IT while fostering the development of social capital among individuals. The IT department can leverage the shared domain knowledge of consultants to gain a certain understanding of the business context of each business department. This understanding enables them to expedite consensus-building in meetings. Meanwhile, the business units can gather the required information for the system in a more targeted manner, thereby accelerating the overall project timeline and enhancing their confidence in the system design plan put forth by the IT department. In light of the challenges faced during the initial implementation, the R&D manager relied heavily on the experience gained from previous implementations of other systems and the guidance provided by the consultants. As stated by the R&D manager, "Our company has previously implemented multiple systems, and while product lifecycle management (PLM) is a relatively large system, the experience of implementing an equally sizable system like enterprise resource planning (ERP) is actually quite limited. Hence, during the initial stages of implementation, we had to rely on our past experiences. However, as the implementation progressed, we realized the need to engage external professional consultants for specific areas."

The literature on digital transformation has emphasized the need for companies to have a culture of innovation to embrace the fruits of new technology (Rolland & Hanseth, 2021). In addition, many companies have achieved successful digital transformations by leveraging their past successes. As suggested by path dependency theory, positive feedback from self-reinforcing mechanisms and past successful transformation experiences enable companies to further strengthen their areas of success (Drechsler et al., 2020; Mahoney, 2000; Wenzel et al., 2017). Nonetheless, our case company demonstrated that past failure experience helped all employees come together and recognize the value of the assistance provided by the system manufacturer's technical consultants. MyComputer has learned that digital transformation projects are not attainable overnight, leading to an adjustment in the employees' mindset and cultural changes. As the inventory manager mentioned, "Although the previous projects resulted in failure, they instilled a mindset among the relevant members that proved to be valuable." Moreover, we found that a crisis is often a turning point for the better. Faced with past failures and the threat of external competitors, MyComputer had to succeed. In line with the 2013 Digital Transformation Report, achieving a successful digital transformation necessitates the establishment of a digital mindset and cultural shift (Fitzgerald et al., 2014). MyComputer reshaped its organizational culture toward greater openness, with senior management actively encouraging discussions across different levels and even throughout the entire organization. Within formal and informal structures, culture serves as an example of an informal element that has an impact on the relationships between the C-suite and IT department (Llamzon et al., 2022). Based on the above argument, we put forth a second proposition:

- *Proposition 2: Past failure experiences, rather than successful experiences, help shape the culture and strengthen the social capital within the organization, ultimately leading to achieving social alignment.*

MyComputer's senior management placed great importance on the backgrounds of project leaders to effectively manage projects from a high-level perspective. Because the project involved the overall process, it was necessary for the process leaders and seed members to possess certain domain knowledge and years of experience to understand cross-plant issues and communicate across departments. This ability allowed them to be trusted and supported by the supervisor who selected the project members. As the inventory manager said, "As the seed member, he or she needs a certain level of company experience to comprehend the original old processes and address any related issues. Moreover, in addition to grasping the existing procedures, the seed member and process owner must also lead the entire team in discussions regarding the direction and ensure that future policies align with the company's vision." Imran et al. (2020) identified digital vision and knowledge as two key leadership competencies required for a digital transformation. Another study conducted by Preston and Karahanna (2009) posited that shared understanding is influenced by the experiential similarity of CIOs and TMTs because individuals with similar functional backgrounds and experiences tend to possess overlapping knowledge bases that make them communicate effectively (Cohen & Levinthal, 1990).

We found that MyComputer has two different leadership styles. First, it adopted visionary leadership, wherein shared domain knowledge and relevant experience enabled leaders to better understand the company's vision, effectively communicate long-term goals, and inspire operational workers (Institute of Project Management, 2022). Second, MyComputer also adopted a delegating leadership style that aligned with its organizational culture (Institute of Project Management, 2022). This style of leadership emphasizes transparency at all levels, thus gradually delegating authority and responsibility to junior employees. As a result, numerous cross-organizational groups were established to enhance the efficiency of the discussions. Delegating leadership positively impacted the group's ability to innovate and collaborate within the team, resulting in increased cohesiveness and trust among group members (Zhang & Zhou, 2014; Zhu & Chen, 2016). Through empowerment and fostering talent, the employees were able to develop a heightened sense of responsibility toward the projects to which they are assigned, fostering a stronger connection and alignment with organizational goals (Seibert et al., 2011). To summarize, shared domain knowledge, leadership experience, and visionary and delegating leadership styles were the three elements of the power of leaders. Power of leaders enabled leaders to gain trust from both superiors and subordinates while leveraging their background knowledge and experience to eliminate unnecessary communication barriers. Encouragement and empowerment expedite the progress of discussions as well. Building on the aforementioned points, we put forth a third proposition:

- *Proposition 3: The power of leadership in terms of visionary and delegating leadership bolsters social capital among employees, which leads to social alignment.*

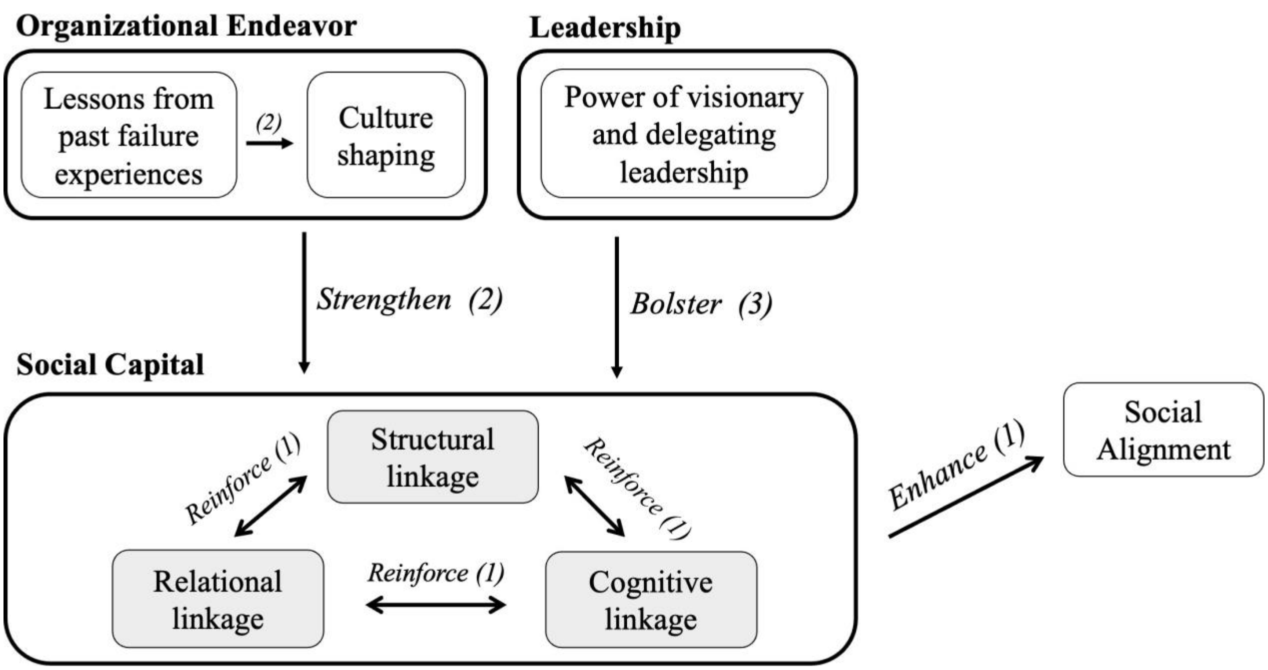


Figure 5. *The Framework of Social Alignment*

Chapter 6. Conclusion

6.1 Summary

In response to our research question, we found that social capital can enhance social alignment and that organizational endeavor and leadership can have a positive influence on social capital, thus strengthening social alignment. We developed a framework that elucidates the relationships among various factors, here aiming to enhance our comprehension of the process involved in attaining social alignment throughout the digital transformation journey. First, our findings have suggested that structural linkage, relational linkage, and cognitive linkage are interrelated and mutually reinforced and that all of them can enhance social alignment. In particular, we found that structural linkage played a dominant role in leading the other two linkages. In doing so, through the restructuring and deployment of organizational resources, relational linkage and cognitive linkage across different functions can be built smoothly. This result provides us with a new perspective on social capital in understanding social alignment. Second, we found that past failures are an exceptionally significant factor. In contrast to successful experiences that companies can replicate, failed experiences assist companies in avoiding the same mistakes and even reshaping their corporate culture while strengthening their social capital to achieve social alignment (Alami, 2016). Finally, our research has underlined that visionary and delegating leadership help bridge the gap between supervisors and subordinates. In the digital age, leaders rely on collaboration and teamwork, which creates innovation and high-performance (Henderikx & Stoffers, 2022). Hence, leaders adopt visionary and delegating leadership styles to inspire and motivate their teams. This encouragement also signifies the leader’s endorsement, empathy, and support for the project and team members (Jakubik &

Berazhny, 2017; Khan, 2020).

Overall, the findings offer a fresh perspective on the factors contributing to the achievement of social alignment. Identifying ways to bridge the gap between IT and business employees to address challenges has been a collaborative effort between academia and industry.

6.2 Implications

Our study has several valuable theoretical implications for existing theory. First, our research has addressed the gap in previous studies that predominantly focused on a single hierarchical level of employees (either the management or operational level). Because top-level executives play a key role in formulating company strategies and performance, prior research has emphasized the shared understanding and shared domain knowledge between IT and TMT (Karahanna & Preston, 2013; Moon et al., 2018). Taking a theoretical perspective on SCT, we have dived deeper into studying cross-level employee relationships by actively participating in overseas factory meetings, cross-departmental workshops, and cross-level discussions. Unlike previous studies that treated social capital as a singular construct (e.g., Afshari et al., 2020; Nuryanto et al., 2020; Schlosser et al., 2015; Wagner et al., 2014), our research has asserted that the three dimensions of social capital (structural, relational, and cognitive linkage) mutually reinforce relationships, emphasizing the importance of structural linkage. Second, previous research on digital transformation has noted the replication of successful experiences as a prerequisite for successful digital transformation in organizations, as highlighted by path dependency theory (Drechsler et al., 2020; Mahoney, 2000; Wenzel et al., 2017). Reich and Benbasat (2000) also considered successful IT history to be one of the antecedents for achieving alignment. Despite this, because of the distinctiveness of the case, our research results suggest that failure experiences and the pressure exerted by a competitive environment are also significant factors in attaining social alignment. Through learning and improvement, failure experiences can also enable a company to change to an innovative and open culture, enhancing social capital among employees.

In terms of practical implications, because we used a case study to explore the factors influencing social alignment, the present research could serve as a reference for future industry participants seeking insights into digital transformation. In particular, many small- and medium-sized enterprises in Taiwan are now facing the issue of digital transformation. They can avoid unnecessary risks or improve their approaches by referring to the factors we have summarized about social alignment. First, allocating IT personnel to different departments based on their diverse domain knowledge would facilitate other business units in building trust in IT personnel and accelerating the formation of shared domain knowledge among them. Additionally, establishing cross-departmental teams from the operational to management level and organizing multiple versions of meetings tailored to different departments and levels would enhance employee engagement and facilitate smoother consensus-building processes. Third, leaders need to recognize the value of past project failure experiences and make appropriate adjustments. It may be necessary to engage external experts with relevant and extensive experience, when needed. These experts will not only bridge the gap between internal employees and the IT department, but can also assist the company in achieving smoother digital transformation by leveraging their previous system implementation experience and industry domain knowledge. Finally, from the perspective of leadership style, delegating authority appropriately can enhance employees' sense of responsibility and engagement. Encouraging teamwork and motivating individuals who aspire to progress can foster creativity and a forward-looking mindset among project members. This enables the overall project to align with the goals set by the company rather than being driven solely by individual convenience.

6.3 Limitations and Future Work

Similar to all empirical research, our research has inherent limitations. First, because of time constraints, our research has focused solely on the initial two stages of MyComputer's digital transformation project: the planning proposal and design stage. The system integration stage was not included. However, our archival data and interviews suggest that demand integration and system design rely heavily on social alignment and are also the stages most likely to cause conflicts between IT and non-IT members. Future research could observe the social alignment formation process throughout the entire transformation project and investigate the factors influencing social alignment at different stages. Second, we considered the external system consultants hired by MyComputer as company employees. Although they were fully involved in the project, like other company employees, whether the different participating roles would result in distinct interaction mechanisms remains a topic for future exploration. Third, our research has centered on the characteristics of the company, such as company culture and leadership style. Although these are important factors in digital transformation, we also acknowledge that employees' individual traits could be potential influencing factors, for example, factors such as employees' age, experience, and level of acceptance of new technologies.

Despite these limitations, we believe that we have provided a fresh perspective in the field of social alignment research on digital transformation. We suggest a re-evaluation of the significance of learning from failure experiences. Furthermore, we propose that changes in organizational structure and resource allocation within companies are vital requirements for strengthening employee relationships and achieving social alignment. We aspire for our research to serve as an inspiration for future endeavors in this domain and to lay the groundwork for theoretical advancements.

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Design Thinking for Service Enhancement: a case of Teaching Assistant as a Service

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Abstract

This study explores the application of design thinking principles for service enhancement in the context of a Teaching Assistant as a Service (TAaaS). The TAaaS is equipped with MLOps capabilities, enabling students to develop and deploy their own new learning algorithms, codes, and AI models by utilizing their own and others' learning modules while enrolled in the New Learning Algorithms course. By integrating design thinking principles, which emphasize empathy, experimentation, and prototyping, this study aims to enhance the user experience and satisfaction in using the TAaaS system. The challenge lies in allowing students to create their own "new learning algorithm" through trial and error, independently from the multiple pipelines, such as model pipeline, deployment pipeline, and prediction service. Through the iterative and user-centric nature of design thinking, this study demonstrates the potential benefits of incorporating design thinking principles into the service design process, ultimately leading to a more successful AI solution tailored to the users' needs and expectations.

Keywords: AIaaS; MLOps; Design thinking; TAaaS; learning algorithm

1. INTRODUCTION

In recent years, artificial intelligence (AI) has undoubtedly become a prominent technology, with AI as a service (AIaaS) emerging as a popular approach to make AI technology more accessible to businesses and individuals (Lins et al., 2021). One subset of AIaaS, Teaching Assistant as a Service (TAaaS), leverages machine learning (ML) operations, or MLOps, such as continuous integration and continuous deployment to facilitate the development and deployment of new learning algorithms, codes, and AI models. Utilizing a TAaaS system for students enrolled in the course on New Learning Algorithms (Tsaih, 2022) offered by the Department of Management Information Systems at National Chengchi University, Taipei, Taiwan, the focus is on implementing design thinking principles to enhance user experience and satisfaction.

AIaaS aims to make AI technology available and affordable to businesses of all sizes and stages of technological development, guiding users through the development, deployment, and inference of analytical models based on data (Elshawi et al., 2018). By eliminating the need for users to master complex algorithms or technical processes, AIaaS allows users to focus on tasks such as training and customizing AI models without worrying about system installation, maintenance, or management (Boag et al., 2018).

MLOps, borrowing tools and procedures from the DevOps movement, simplifies the development and deployment of ML models (Kreuzberger et al., 2022). Automation of ML model training and testing, integration of ML processes with version control systems, and consistent container deployment are key aspects of MLOps.

Norman (2017) indicated that for AI systems to be effective in the field of education, they must fundamentally be human-centered, addressing the genuine, underlying needs of their intended users. These systems should be structured around the capabilities and requirements of both learners and educators, ensuring that the developed solutions are practical and yield significant benefits. This human-centered design approach aligns well with design thinking, a problem-solving methodology that involves empathy, experimentation, and prototyping. It is an important trend in AI research, as highlighted by Stembert and Harbers (2019), and Riedl (2019), emphasizing the creation of AI solutions that are easy to learn, use, and customize for specific user segments.

In this study, we employ an iterative approach to investigate the influence of research methods on AI services, utilizing TAaaS as our case in this experiment. This TAaaS system covers AI Software Services and AI Developer Services, assisting students in creating new learning modules and integrating existing ones into their learning algorithms. The intention behind this iterative approach is to discuss the impact of design thinking on service design and user experience. This user-centric approach, with its stages of empathizing, defining, ideating, prototyping, and testing, has been fundamental in ensuring that the system is tailored to address user needs, thereby enhancing their overall learning experience. Our exploration centers on three main dimensions:

1. We investigate the feedback collected from two cycles of user interaction and design thinking process (DTP_1 and DTP_2).
2. We compare the user interface and user experience (UI/UX) of two iterations of our service (TAaaS_1 and TAaaS_2).
3. We explore the insights derived from the counter-comparison of the two versions differences.

In conclusion, this study underscores the significance of integrating design thinking principles into the development of AI services like TAaaS. It offers insights into the benefits of a user-centered design approach in creating an intuitive and effective educational tool, thereby contributing to the wider AIaaS and MLOps fields.

2. LITERATURE REVIEW

2.1. Artificial intelligence

The advancement of AI is often discussed in terms of how it contributes to human progress. The recent advances in ML have led to expectations of enhanced efficiency as well as new and improved services for customers and society. These advancements are supported by enormous volumes of accessible data, as well as quickly expanding computer capabilities and public tools and libraries (Stahl et al., 2021). AI is a broad field that deals with the development of intelligent systems that can exhibit human-like behavior and intelligence. AI systems can perform tasks that typically require human intelligence, such as visual perception, speech recognition, decision-making, and language translation (Lu, 2019). ML is a subfield of AI that focuses on the development of algorithms and models that can learn from data and improve their performance over time (Nagarhalli et al., 2021). ML algorithms use statistical techniques to enable computers to learn from data without being explicitly programmed (Dhillon et al., 2022). Deep learning (DL) is a type of ML that involves the use of neural networks, which are algorithms inspired by the structure and function of the human brain. DL is particularly useful for tasks that involve large and complex datasets, such as image and speech recognition (Zhang and Lu, 2021).

To train DL models, we use learning algorithms, which adjust the model's parameters based on the data it is presented with to make the model more accurate and effective at performing a task (LeCun et al., 2015). These algorithms are used to optimize the parameters of a ML model by minimizing the error between the predicted output and the true output. In general, learning algorithms iteratively adjust the model's parameters based on the input data and the corresponding output labels. The goal is to find the set of parameters that minimizes the error between the predicted output and the true output, so that the model can make accurate predictions on new, unseen data (Shrestha and Mahmood, 2019).

In conclusion, AI offers promising prospects for making positive contributions to the accomplishments and inventiveness of organizations and the progress and development of the community (Rai et al., 2019). The fast development of AI has led to significant changes in people's lives.

2.2. Artificial intelligence as a service (AIaaS)

AIaaS, which stands for "artificial intelligence as a service" or "cognitive services" is a type of cloud-based service that gives businesses and people access to AI tools and apps over the internet (Barlas et al., 2021). As AIaaS is a cloud service, it inherits the advantages and qualities that have established cloud services as a vital information infrastructure for our daily lives.

Cloud services provide ubiquitous, convenient, on-demand network access to a shared pool of customizable computing resources (e.g., networks, servers, storage, applications, and services). These resources may be immediately delivered and released with minimal effort required from the administrative side or the service provider. In addition, Mell et al. (2011) defined a model of cloud computing that is made up of a total of five essential characteristics, three service models, and four deployment models, which are detailed as follows:

- Essential characteristics includes on-demand self-service, broad network access, resource pooling, rapid elasticity, and measured service.
- Service models contains software as a service (SaaS), platform as a service (PaaS), and infrastructure as a service (IaaS).
- Deployment models covers private cloud, community cloud, public cloud, and hybrid cloud.

AIaaS can include a wide range of services, such as machine learning algorithms, natural language processing, image recognition, and more. AIaaS providers typically offer these services on a subscription or pay-per-use basis, making it more accessible and affordable for businesses and individuals to use AI technology. The concept of AIaaS was conceived because of the intersection of cloud computing and artificial intelligence. AIaaS may be defined as cloud-based platforms that provide on-demand services to people and businesses for developing, training, deploying, and managing AI models (Lins et al., 2021).

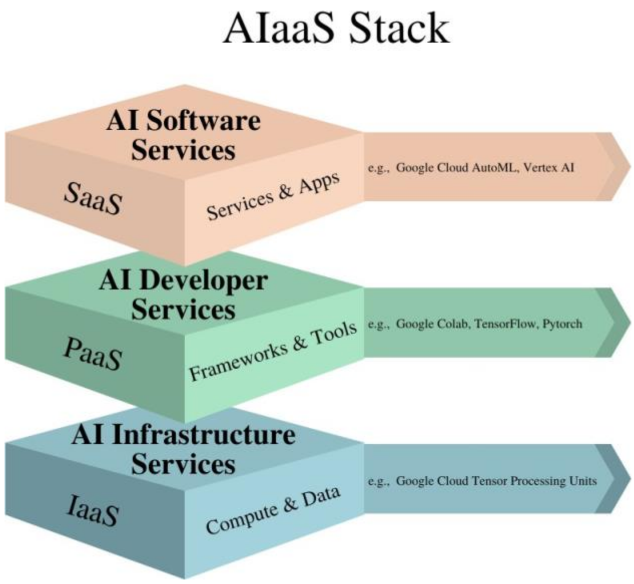

Figure 1 AIaaS stack revised from (Lins et al., 2021).

2.3. Machine learning operations (MLOps)

MLOps is a concept for incorporating ML into the DevOps lifecycle, which is a software development lifecycle. DevOps integrates software development (Dev) and IT operations (Ops) (Ebert et al., 2016). DevOps aims to reduce the development life cycle and deliver applications more often while assuring stability and reliability. DevOps automates software development and IT operations to ensure continuous delivery of high-quality products. It enables firms rapidly deliver apps and services to better serve customers and compete in the market. Continuous integration, delivery, and deployment are DevOps approaches that do this. Automation of build, test, and release procedures and infrastructure management are part of these techniques. DevOps also emphasizes collaboration, communication, and integration between development and operations teams (Leite et al., 2019).

MLOps involves using tools and processes to improve collaboration and communication among data scientists, software engineers, and operations professionals, and to automate the deployment and management of machine learning models (Kreuzberger et al., 2022). This includes managing the infrastructure and runtime environments for ML models, keeping track of how well they work and how accurate they are, and putting models into "production stage".

Figure 2 depicts a MLOps level 2 architecture proposed by Google Cloud Architecture Center (2020). Some key functions are as follows.

- Source control: This refers to the use of version control systems, such as Git, to monitor and manage changes to the source code and other artifacts associated with an ML project. This ensures that various code versions can be traced and that any modifications made to the codebase can be readily monitored and rolled back if required.
- Test and build services: These are tools and services that are used to automate the testing and building of AI models. This includes tasks such as unit testing, integration testing, and continuous integration (CI).
- Deployment services: These are tools and services that are used to automate the deployment of AI models to "production stage". This may include tasks such as packaging and releasing code, managing infrastructure, and performing canary releases.
- Model registry: This is a central repository that stores and manages machine learning models and their associated metadata. It allows teams to track the lifecycle of a model, including its training data, performance metrics, and any updates or changes made to it over time.
- Feature store: A feature store is a central repository for storing and managing the features that are used to train machine learning models. It allows teams to track the lifecycle of features, including their origin, transformation, and usage, and to make them easily accessible to data scientists and engineers.
- ML metadata store: This is a repository for storing and managing metadata related to machine learning projects. It may include information such as model training data, hyperparameters, and performance metrics.
- ML pipeline orchestrator: This is a tool or service that is used to automate the orchestration of machine learning pipelines. It may be used to schedule and execute pipelines, monitor their progress, and track their results.

Overall, MLOps aims to improve the efficiency and reliability of machine learning projects by standardizing and automating processes, and by providing tools and services that support collaboration and traceability.

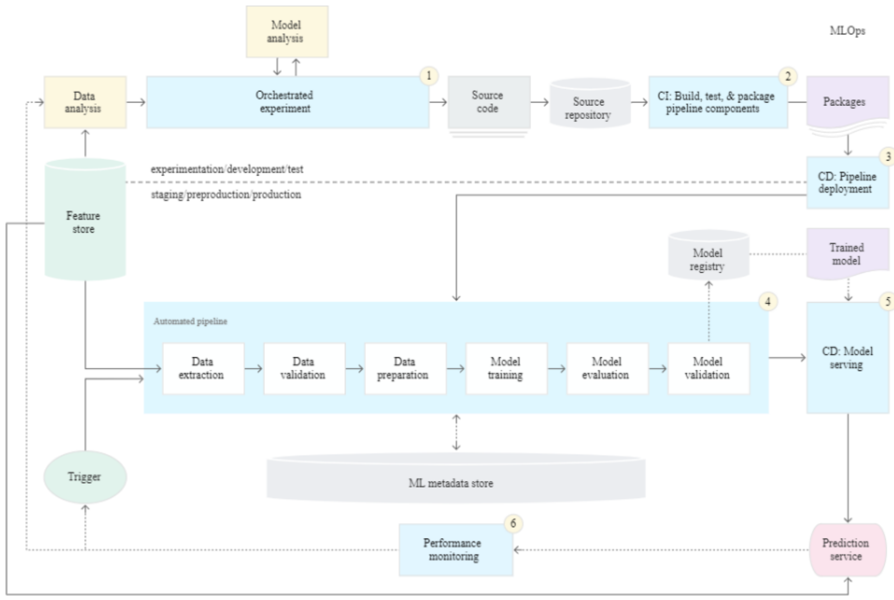

Figure 2 MLOps level 2: CI/CD pipeline automation (Google Cloud Architecture Center, 2020).

2.4. Human-Centered Design and Design Thinking

Human-centered design is a design framework which prioritizes user needs and experiences and has become a significant movement worldwide. According to human-centered design pioneer Donald Norman, modern design should focus on the needs of those who will interact with the product or service because every product or service involves people (Gasson, 2003, Norman, 2017, Xu, 2019).

Design thinking (DT) is a human-centered and user-centric interactive approach to innovation and problem solving (Brown et al., 2008). It is a methodology for the teams or organizations to design better products, services, or experiences and it has been applied in many fields such as healthcare, business, education, IT Industry and more (Hasso Plattner Institute of Design at Stanford University, 2023).

Nobel Prize laureate Herbert A. Simon (Brown and Martin, 2015) first advanced the concept of DT in 1969, defining design as "transformation of existing situations into preferred ones" and design thinking as "way of thinking." The DT well-known guru Tim Brown, the co-chair of global design and innovation firm IDEO, describes DT as "a human-centered approach to innovation." Design thinking has been developed by researchers of Stanford d. school and the IDEO (Kelley, 2001). The overall objective of DT is to generate innovative concepts based on a deep understanding of what users need and want to create a desirable, feasible, and viable solution. It is an iterative, non- linear process by which there are three spaces to keep in mind: inspiration, ideation, and implementation, for developing new ideas in an innovative and user-centered way (Brown and Katz, 2011).

Studies showed DT can make valuable contributions to software development and create products or services based on user needs. Lindberg et al. (2011) mentioned that DT can help engineers to define problems more precisely so that their expert knowledge may be applied suitably. Pereira and de F.S.M. Russo (2018) noted that the use of a DT approach helped checking both technical and non-technical factors and their study showed in some cases the quality of the software and the satisfaction of the users significantly increased.

There are five important phases of the DT cycle: 1. empathy toward users, 2. defining the problem, 3. ideation, 4. prototyping, and 5. testing; the phases would move through the cycle iteratively (Hasso Plattner Institute of Design at Stanford University, 2023). The users are always at the center of the different process phases. DT begins with understanding the challenges and empathizing with the end users. Then it gathers insights and identifies the problems, and at the third phase it generates ideas and solutions, then following by prototyping, testing, getting users' feedback and iterating.

An experimental study on Deutsche Bank's IT division showed that the DT approach helped integrate customers into the organization's innovation process and provided an efficient and effective way to launch user-centric service in a short time (Vetterli et al., 2016). IBM has been using DT to explore the problems and uncover the clients' spoken and unspoken needs and wants, and then validate and iterate before a product or service released to the market (Clark et al., 2008, Lucena et al., 2017).

Verganti et al. (2020) point out that AI reinforces the principles of DT, especially human-based activities often requiring significant investment of resources and time. Their study showed that

DT and AI can empower each other. DT helps empower a more effective, human-centered implementation of AI, and AI helps empower a more advanced practice of DT. They noted that, AI is intrinsically iterative and delivers through loops. The loops can leverage the most recent data and algorithms, and also offer a new opportunity of further learn.

3. RESEARCH METHODOLOGY

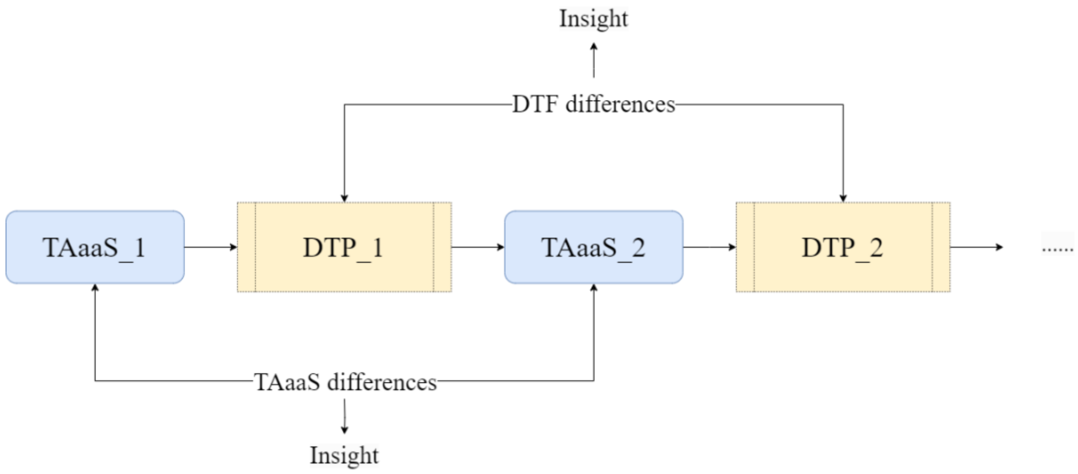

Figure 3 Research methodology diagram

This research aims to explore the influence of design thinking on service design and user experience, with a focus on an iterative process that incorporates user feedback at multiple stages. In the first design thinking process (DTP), participants interact with the initial version of the Teaching Assistant as a Service, referred to as TAaaS_1, which has been developed without explicit use of design thinking principles. TAaaS_1 integrates the functionalities of AI Software Service, AI Developer Service, and Machine Learning Operations (MLOps) to facilitate a more effective learning process for students engaging in AI studies. A detailed system architecture is discussed in Chapter 4.

Feedback derived from this interaction form the foundational structure of design thinking feedback (DTF), primarily focusing on user satisfaction, the usability of the system, and the overall participant experience. This approach is consistent with the principles of design thinking outlined by Brown et al. (2008), which emphasize a user-oriented, iterative process encompassing the understanding of user behaviors, empathizing, ideating, and testing prospective solutions. Through DTP_1, we define the challenges within TAaaS_1 based on feedback (DTF_1) from participants, thereby instigating the ideation process and leading to the creation of enhanced service prototypes. Following additional rounds of user feedback, these prototypes are refined, leading to the development of the redesigned service, TAaaS_2. Each participant experiences both the initial and redesigned services, which allows us to control for individual differences and potential confounding variables. Upon completion of the interaction with both versions of the service, participants' feedback is collected again to evaluate their experience with the redesigned service, TAaaS_2. The comparison of participant responses to the two versions of the service allows us to assess whether the application of design thinking principles through DTP_1 has led to significant improvements in service design and user experience. This cyclical process is broken down into three sections:

1. Differences in feedback gathered from the two cycles of user interaction and design thinking process (DTP_1 and DTP_2).
2. Differences in UI/UX between the two iterations of our service (TAaaS_1 and TAaaS_2).
3. Insight derived from the counter-comparison of the two versions differences.

In conclusion, this integrated research methodology allows us to systematically investigate the impact of design thinking on service design and user experience. Utilizing the iterative design approach, and comparing participants' responses to the two service iterations, we aim to provide valuable insights into the potential benefits of incorporating design thinking principles into the service design process, keeping in view users' perspectives and feedback.

4. THE TAAAS AND ITS IMPLEMENTATION

In this research, our primary focus is exclusively on examining the UI/UX components of TAaaS. While TAaaS is inspired by and indeed incorporates elements of the Google's MLOps level 2 concept, specifically CI/CD pipeline automation (Google Cloud Architecture Center, 2020), and also integrates the AI Software Services and the AI Developer Services from the AIaaS stack (Lins et al., 2021), we will not be delving into these aspects in detail. Our intention is not to explore the intricacies of MLOps or the broader AI service offerings, but to concentrate solely on how the UI/UX elements of TAaaS can be optimized and improved. This means the investigation will be directed at understanding and enhancing the way users interact with and experience TAaaS, with no in-depth discussion on MLOps. Consequently, the architecture of the system under review is divided into two sections, aimed at providing AI Software Services and AI Developer Services, respectively, but our research will only be concerned with the UI/UX facets of this arrangement.

4.1. The AI Software Services

Lins et al. (2021) described AI software services as ready-to-use AI applications and building components, akin to the traditional SaaS (Software as a Service) cloud layer. For users seeking to utilize an existing model, the AI Software Services provide pipelines and modules. The development team is responsible for creating new pipelines and modules that allow users to complete the model pipeline, deployment pipeline, and prediction service within the MLOps framework. In this study, we initially developed a pipeline for homework 1 (Figure 4), assigned in the New Learning Algorithms course, to facilitate the experiments we conducted in the Chapter 5.

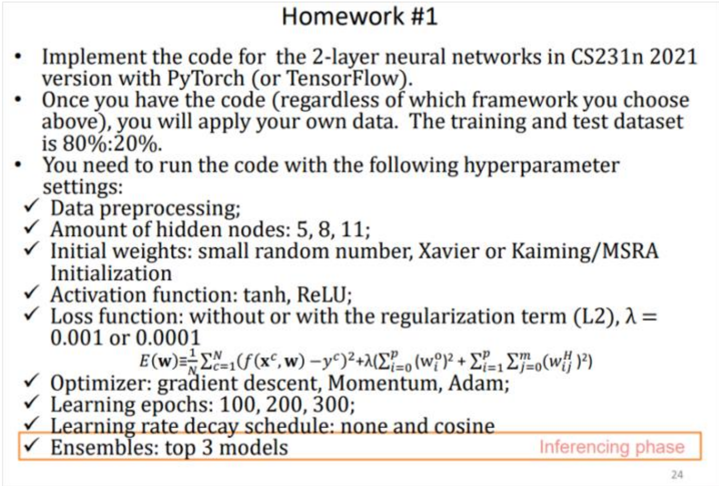

Figure 4 Homework 1 assigned in the New Learning Algorithms course

4.2. MLOps for The AI Software Services

The AI Software Services are responsible for supporting users in directly creating and deploying neural network models in the “production stage” by using the pre-defined pipelines developed in the “development stage” by the system engineer. The terms “development stage” and “production stage”, which refer to the concept of MLOps, compose the diagram depicting the proposed implementation of MLOps of the AI Software Services (Figure 5). When users attempt to upload datasets, train new AI models, and implement those models in services, these steps are done in the AI Software Services. Under the proposed implementation of MLOps of the AI Software Services, the flow architecture in the “development stage” is nearly equivalent to the original architecture (Google Cloud Architecture Center, 2020). Instead, the flow in the “production stage” differs as follows:

1. Model pipelines:
    a. Data preparation: we exclude certain data-related components, such as data analysis and data extraction, because users in this use case should prepare the dataset before accessing the pipelines. When users finished the step of data preparation, the uploaded datasets would be stored as CSV files on the server and organized into folders depending on the data subjects and data usage. Data subjects include, but are not limited to, “solar power generation forecast” and “prediction of low birth weight in newborns.” Data usage includes “training” and “testing” datasets.

b. Model training: this proposed model pipeline covers model training pipelines of homework 1, assigned in the New Learning Algorithms course.

c. Model validation: there is a difference between the definition proposed by Google Cloud Architecture Center (2020). The procedure for assessing the stability and generalizability of an AI model is the definition we agreed on. Typically, model validation is accomplished by splitting the data into training and validation sets and utilizing the validation set to measure the performance of the model. The purpose of model validation is to confirm that the model has not overfitted to the training data and can accurately predict new, unobserved data (Goodfellow et al. 2016).

d. Model evaluation: the model is evaluated on the training dataset and the validating dataset, which are split in the ratio of 8:2 from the original training dataset. The output of this step is a set of metrics and figures to assess the quality of the model. Furthermore, the model's metrics and figures will be stored on the server.

2. Deployment pipeline:

    a. Model deployment: the deployment state of models is stored on the MongoDB container; after a model has been deployed, the deployment status of that model will switch from "revoking" to "deploying." The GitLab CI/CD tool will then immediately and automatically start the deployment of the model through Docker on the server.

    b. CD: Image building: the step of building a Docker image based on the deployed model.

    c. CD: API building: the step of building a Docker container based on the built image. After the container is completely enabled, the information about the container, which is the model that has been deployed, such as the container ID and port, will be updated in the MongoDB container, and then the web-based UI will be updated synchronously.

3. Model API: after the CD pipeline is finished, the enabled container becomes an AI model API.

4. Prediction service:

a. Data preparation: this step in the prediction service is substantially similar to the step in the model pipeline, with the exception that the testing dataset is employed here.

b. Model prediction: the main service will request the Docker container and obtain the loss function value for the testing dataset.

c. Performance monitoring: the loss function value of the testing metric, as well as the data from previous training experiments, will be imported into the server from the metadata file corresponding to the model.

5. Manually trigger: the component of continuous training in the original architecture (Google Cloud Architecture Center, 2020) is manually triggered here because it is not an essential function in this use case. As a result, we designed the web-based UI for users to check the model's performance by themselves.

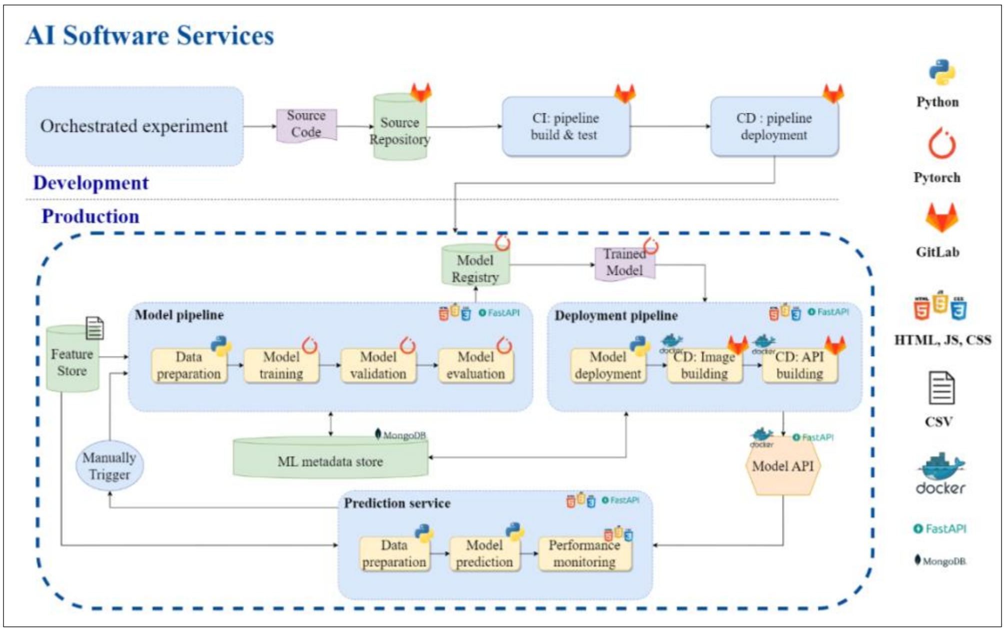

Figure 5 The proposed implementation of MLOps of the AI Software Services.

4.3. The AI Developer Services

Lins et al. (2021) characterized AI Developer Services as tools designed to assist developers in implementing code to unleash AI capabilities, analogous to the traditional PaaS (Platform as a Service) cloud layer. For users aiming to develop new algorithms, the AI Developer Services offers a range of tools and resources to create and deploy learning modules within the AI Software Services.

The development team plays a crucial role in designing and maintaining these tools, ensuring seamless integration with existing pipelines and modules. In this study, we leveraged the AI Developer Services to build custom algorithms tailored to the specific requirements of homework 1 in the New Learning Algorithms course, which we then utilized in the experiments detailed in Chapter 5.

4.4. MLOps for The AI Developer Services

The primary duty of the AI Developer Services is providing users with the resources and materials necessary to construct and deploy learning modules from the "development stage" to the "production stage." This transition takes place from the "development stage" to the "production stage." The terms "development stage" and "production stage", which refer to the concept of MLOps, compose the diagram depicting the proposed implementation of MLOps of the AI Developer Services (Figure 6). Both the MLOps and DevOps theories constantly make reference to the two stages that we went over in the previous section. Users with the objective of using an existing model are closer to the "production stage" in the AI Software Services of this proposed TAaaS, whereas users with the objective of developing new algorithms are closer to the "development stage" in the AI Developer Services. Traditionally, the "development stage" of MLOps has been designated for data engineers and data scientists, who utilize it to design pipelines and conduct experiments. In this study, when users attempt to build new learning modules, which is referred to as the "development stage," and once the submitted learning module has been validated and deployed to the "production stage," are the AI Software Services able to apply the new learning modules. According to the MLOps that have been proposed for the AI Developer Services, the flow architecture in the "development stage" is partially analogous to the architecture that was originally designed. Alternatively, the flow is different in the "production stage," as follows:

1. Orchestrated experiment: the orchestrated experiment in "development stage" often refers to the ability for researchers or engineers to explore the topic in which numerous components or pipelines are coordinated and controlled to generate a desired result. In this research,

however, users rather than a system engineer were designated for this task. Developer users are distinguished from the software users in that they only apply to previously defined pipelines in the "production stage". They can construct a customized pipeline component, which primarily relates to learning modules, and deploy it in the "production stage," making customized learning modules available to software users.

2. CI/CD: module build, test, and deployment: there exists a distinction between the AI Software Services and the AI Developer Services. In the first scenario, Docker will not be used to perform pipeline operations. Because in the latter scenario, we would conduct any testing necessary on container.
3. Module API: after the CI/CD pipeline is finished, the enabled container becomes a learning module API.
4. AI Software Services: the generated learning module API is now accessible to the model pipeline in the AI Software Services.

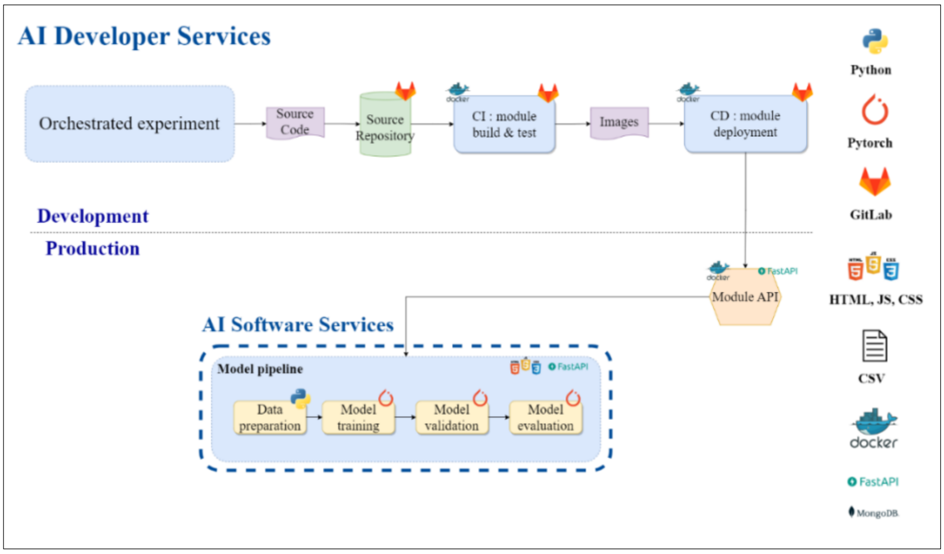

Figure 6 The proposed implementation of MLOps of the AI Developer Services.

5. EXPERIMENT

5.1. Research participants

The participants in the study were selected based on the quality of their submissions for homework 1 in the course on New Learning Algorithms offered by the Department of Management Information Systems at National Chengchi University, Taipei, Taiwan, as determined by a review process. The process emphasizes whether the students go beyond the basic requirements of completing the assignment and even engage in further comparisons and analyses among different models.

The study group consisted of 5 participants who conducted the experiments together. They are between the ages of 23 and 31, with an average age of 25.4 years. There are 2 males and 3 females in the group. All of the respondents are in a Master's program, with 4 in their first year and 1 in their second year. The most common age in the group is 24, which is also the median. The standard deviation of the ages is 2.97, indicating that the ages are relatively close to the mean.

5.2. Experiment design

5.2.1. DTP_1

We are selecting participants from students who have previously completed homework 1 in order to ensure that these participants satisfy the first step of the design thinking cycle: empathy. The participants are instructed to complete several tasks using TAaaS_1.

Table 1 Experiment tasks in DTP_1

- Task 1 - AI Software Service phase

1. Use your personal laptop to enter the TAaaS entry website: http://140.119.19.87/entry
2. Follow the webpage path to enter the hw1 page: AI Software Service -> Model pipeline -> Homework #1.
3. According to the instructions on the webpage, fill in the required hyperparameters for model training and train a model in sequence. Note that there is no need to upload a dataset under data preparation, as you can use the system' s default dataset (e.g., hospice, solar).
4. Check the model performance and training configuration.

- Task 2 - AI Developer Service phase

1. Use your personal laptop to enter the TAaaS entry website: http://140.119.19.87/entry
2. Enter the AI Developer Service UI.

3.	Download the example program for homework 1.
4.	Follow the instructions in the hw1.py program to complete the steps.
5.	Fill in the required fields.
6.	Compress the hw1.py program.
7.	Rename the compressed file as hw1-student ID.zip, e.g., hw1-110356021.zip.
8.	Return to the AI Developer Service UI and upload the compressed file.
9.	Enter the Ensemble page and search for the trained model using your student ID.
●	Task 3 - Ensemble phase
1.	First, train at least three models on AI Software Service/AI Developer Service using the same dataset configuration.
2.	Enter the Ensemble page: http://140.119.19.87/pipeline/model/hw1/ensemble
3.	Search for the trained model using your student ID.
4.	Use the sorting function in the table to view the training loss or validating loss of the models in different orders.
5.	Select the top three models with better training results and submit.
6.	Check the validating loss of the Ensemble model.

After completing the tasks, we engage in a discussion about the user experience of The TAaaS_1 by addressing the following questions.

Table 2 Discussion topics in DTP_1

1	Do you think the information provided on the UI can guide you to complete the required task? Why?
2	Do you think this UI provides sufficient guidance and assistance to help you complete the required task? Do you need additional help or guidance to complete the task?
3	What are the differences between completing the assignment on your own and completing it with the assistance of the system?
4	When completing assignments on your own, what system-assisted tools do you consider using? How do these tools help you complete tasks more effectively?
5	Do you think the overall use process is smooth? Did you encounter any difficulties or setbacks? Is there any part that confuses you or makes you want to stop using it?
6	Based on your user experience, are there any elements that can be added to the website to help you complete the task more smoothly?
7	Briefly describe your feelings after using the system today.
8	If you use the system first and then complete the assignment on your own, does it deepen your learning process?

5.2.2. DTP_2

The participants are instructed to complete several tasks using The TAaaS_2.

Table 3 Experiment tasks in DTP_2

●	Task 1 - AI Software Service phase
1	Access the TAaaS portal using your personal laptop at http://140.119.19.87/entry.
2	Navigate to the hw1 page under AI Software Service -> Model pipeline -> Homework #1.
3	Follow the on-screen instructions to complete the model training process using the system's default datasets (e.g. hospice, solar).
●	Task 2 - AI Developer Service phase
1	Access the TAaaS portal using your personal laptop at http://140.119.19.87/entry.
2	Navigate to the online editor page under AI Developer Service.
3	Follow the on-screen instructions to complete the model training process.
4	If the process is completed successfully, you will be automatically redirected to the Ensemble page.
●	Task 3 – Ensemble phase
1	Using the same dataset, train three or more models using the first two services.
2	Access the Ensemble page at http://140.119.19.87/pipeline/model/hw1/ensemble.
3	Search for the trained models using your student ID.
4	Use the website's features (e.g. model training information, table sorting) to select the top three best-performing models and submit your choices.
5	Check the validating loss of the ensemble model.
●	Wait patiently for the other participants to complete the experiment.
●	You can take notes about your experience with the system in the provided document.

After completing the tasks, we engage in a discussion about the user experience of The TAaaS_2 by addressing the following questions.

Table 4 Discussion topics in DTP_2

1	Do you think the information provided on the UI is sufficient to guide you in completing the required tasks? Why?
2	Do you think this UI provides sufficient guidance and assistance to help you complete the required task? Do you need additional help or guidance to complete the task?
3	What are the differences between completing the assignment on your own and completing it with the assistance of the system?
4	Do you think the overall use process is smooth? Did you encounter any difficulties or setbacks? Is there any part that confuses you or makes you want to stop using it?
5	Based on your user experience, are there any elements that can be added to the website to help you complete the task more smoothly?
6	Did making improvements to the system based on the feedback received from classmates during the DTP_1 make it better aligned with the needs of the students in the class?

7	Briefly describe your feelings after using the system today.
8	If you use the system first and then complete the assignment on your own, does it deepen your learning process?

5.3. Feedback difference between two DT cycles

5.3.1 DTP_1

During the study, participants are asked to complete multiple tasks using The TAaaS_1, followed by a discussion of their user experience. In the design thinking cycle, step 2 entails defining the problem. The feedback collected from discussions reveals a range of user experience issues. These issues, impacting the learning process, represent the "problems" we aim to define in this step. Some students report that the process is smooth, while others encounter difficulties such as unclear operations and opaque mechanisms behind the Ensemble function. Regarding the impact of the system on the learning process, responses are mixed, with some students finding it helpful for understanding hyperparameters, but still needing to write the code themselves. Others feel that the system do not significantly aid their learning experience.

These feedback suggestions, including adding system elements such as remembering previous training hyperparameters, providing comment guidance, and allowing a code editor on the webpage, are the outcomes of the design thinking cycle step 3: ideation. This table presents user feedback as design thinking feedback (DTF) on expectations and suggested improvements for the service. It is created by the research team after gathering ideas from participants who use the service during the study.

Table 5 Feedback derived from the DTP_1

Index	Category	Feedback
DTF_1-1	Function	Provide field memory and layout retention functionality to enhance user experience.
DTF_1-2	UI	Provide a flowchart to help users clearly understand the entire process steps.
DTF_1-3	UI	Structure blocks, including data preparation, model training, and model performance, to differentiate different sections.
DTF_1-4	UI	Provide a pop-up window to view model training hyperparameters for easy comparison and analysis.

DTF_1-5	Function	Provide external links for forward and backward knowledge to help users better understand the operational principles of the model.
DTF_1-6	Function	Provide data description functionality to more clearly explain the features and attributes of the dataset.
DTF_1-7	Function	In addition to loss value, provide output value for a more comprehensive evaluation of model performance.
DTF_1-8	Function	Allow users to download model files and code for further application and improvement.
DTF_1-9	Function	Provide a usage comparison table for different packages, such as PyTorch and TensorFlow, to facilitate users in selecting the appropriate package.
DTF_1-10	Function	Support compatibility between multiple package usages to enhance system openness and flexibility.
DTF_1-11	Function	Ensemble mechanism is unclear.
DTF_1-12	Function	Provide more text descriptions (comments) to explain the use of hyperparameters, helping users better adjust model design and parameters.
DTF_1-13	Function	Provide compiler extension functionality to improve the efficiency and convenience of writing code for users.
DTF_1-14	Function	Provide compiler and debug functionality to improve the efficiency and convenience of writing code for users.

After making these following adjustments, the outcome is TAaaS_2, which incorporates the selected feedback and ideas from Table 5(including: DTF_1-1, DTF_1-2, DTF_1-3, DTF_1-4, DTF_1-8, DTF_1-12, and DTF_1-13) into the system's functionality, following step 4 of the design thinking cycle: prototype. We will complete the final stage of the entire design thinking cycle, which is testing, within DTP_1. This involves conducting a full DT process again in DTP_2.

5.3.2 DTP_2

During step 1 of DTP_2, participants have already met the conditions for double empathy: they have completed homework 1 from the class and the TAaaS_1 experiment. As for steps 2, 3, and 4, they follow the experimental procedure of DTP_1.

During the discussion, participants shared their experiences using the redesigned TAaaS_2 system to complete various tasks. Most of them found the process smooth and appreciated the step-by-step guidance provided. They also encountered some difficulties, such as the lack of warnings for missing hyperparameters in the Developer section and the unclear operations in the Ensemble function. Participants provided valuable feedback, suggesting the addition of features like visualizing loss comparisons, offering back buttons for easier navigation, and enhancing Ensemble function usability.

In terms of the system's impact on learning, students had mixed opinions. Some found it helpful for understanding hyperparameters and facilitating the completion of tasks, while others still preferred writing the code themselves for a greater sense of accomplishment. Overall, most participants agreed that the system, particularly after incorporating feedback from DTP_1, better addressed the needs of students taking the course.

This table presents user feedback on the expectations and suggested improvements for the service. It was created by the research team to gather feedbacks from participants who used the service during the study.

Table 6 Feedback derived from the DTP_2

Index	Category	Feedback
DTF_2-1	UI	Provide a button that allows users to return to the initial stage of the training process, making it easier to retrain the model.
DTF_2-2	UI	On the Entry page, include a section that leads directly to the Ensemble feature, corresponding to the three task topics.
DTF_2-3	UI	On the Ensemble page, prompt users to select 1 to N models before submitting, and add a section to directly access the Ensemble feature.
DTF_2-4	Function	Add loss charts to the model links so users can view the training results.
DTF_2-5	Function	In the Ensemble page, use a visualization interface to display the loss comparison charts of all or selected models.
DTF_2-6	UI	Choose a single presentation method for the Online Editor and the code upload/download feature to avoid confusion.
DTF_2-7	Function	Add foolproof features for hyperparameters in the Developer panel, such as warnings for empty value submissions.

5.3.3 Comparison between two DT cycles

Design thinking is a systematic, human-centered approach to problem-solving that is typically applied to improve product design, user experience, and user interface. In both DTP_1 and DTP_2, feedback was gathered from users who interacted with the TAaaS system. The feedback from these sessions were used to understand user pain points, usability issues, and areas of improvement for the system.

1. DTP_1: During the first session, participants reported a mixed experience using The TAaaS_1. Issues included unclear operations and the lack of a transparent mechanism behind the Ensemble function. However, participants also provided valuable feedback that helped identify areas for system improvement. These suggestions were largely centered on enhancing the software's user experience and functionality, with suggestions such as adding system elements for remembering previous training hyperparameters, providing a flowchart for the process, and allowing for a code editor on the webpage. The developer-related feedback focused on improving code-writing efficiency and convenience.
2. DTP_2: After incorporating feedback from the first session, the second round of design thinking was conducted on the redesigned TAaaS_2 system. Participants found this iteration smoother, with step-by-step guidance provided. However, there were still issues identified, such as the lack of warnings for missing hyperparameters and unclear operations in the Ensemble function. The feedback from this round of testing was geared toward additional feature suggestions, such as visualizing loss comparisons and offering back buttons for easier navigation. User suggestions also focused on better streamlining and user-proofing the developer section of the service.

Overall, it appears that the iterative design thinking process helped improve the system from TAaaS_1 to TAaaS_2, with feedback from users being incorporated into design changes that increased overall user satisfaction and addressed user needs more effectively. However, both rounds also highlighted that further improvements could still be made, particularly in the areas of system clarity, user guidance, and feature augmentation.

5.4. UI/UX difference between two services

The following table outlines the features and reasons for improvement that I have chosen based on user feedback gathered by the research team during the study.

Table 7 Selected feedback from DTP_1 for Improvement

Index	Improve	Reason
DTF_1-1	Y	Enabling fields to remember previous input values and the webpage to remember the previous layout position can enhance user experience and efficiency.
DTF_1-2	Y	Providing a flowchart can improve user understanding and mastery of the entire process.
DTF_1-3	Y	Segmenting blocks for data preparation, model training, and model performance can help users better understand and operate them.
DTF_1-4	Y	Providing a pop-up window to view model training hyperparameters by clicking on a model in the model list can make it more convenient for users to compare and analyze models.
DTF_1-5	N	The feature requiring additional external links may increase development time and cost as it requires additional research and organization, potentially adding unnecessary confusion and learning burden for users. Therefore, it may be temporarily shelved.
DTF_1-6	N	Providing more detailed data descriptions may require more time and resources for organization and editing, and may undergo significant changes due to differences in data format and type, increasing development cost and time. Therefore, it may be temporarily shelved.
DTF_1-7	N	Providing more training information may require more detailed monitoring and output of the model, increasing development time and cost and potentially affecting the model’s efficiency and accuracy. Therefore, it may be temporarily shelved.
DTF_1-8	Y	There is already a feature to download model files, but providing an additional feature to download code may require more complex processing and potentially create additional issues due to differences in code type and format. Therefore, it may be temporarily shelved.
DTF_1-9	N	Organizing and comparing different packages for a usage comparison table may require more time and resources for organization and editing and may undergo significant changes due to differences in

		package version and functionality. Therefore, it may be temporarily shelved.
DTF_1-10	N	Integrating and adjusting different packages for compatibility may require more time and resources for organization and editing and may undergo significant changes due to differences in package version and functionality. Additionally, since this feature may only apply to specific users, not all users require this functionality, and temporarily not developing it can reduce development cost and time.
DTF_1-11	N	Since the Ensemble mechanism is unclear, developers may need to conduct more research and testing to determine the appropriate implementation method, increasing development time and cost. Additionally, since this feature may only apply to specific users, not all users require this functionality, and temporarily not developing it can reduce development cost and time.
DTF_1-12	Y	This feature can provide more detailed explanations to help users better understand the purpose of hyperparameters and how to adjust them.
DTF_1-13	Y	Providing compiler extension functionality can improve user efficiency and convenience in writing code.
DTF_1-14	N	The feature requiring additional debugging functionality may require more complex processing of the code, increasing development time and cost. Additionally, users may already be using other debugging tools while writing code, so it may be temporarily shelved.

Here is a list of feedback I obtained from DTP_1 and selected as improvement requirements for the system. I have also provided a system screenshot for reference.

- DTF_1-1

Initially, in TAaaS_1, the web form fields had fixed default values. After the adjustment based on the feedback from DTF_1-1, they were modified to retain the user's previous input data.

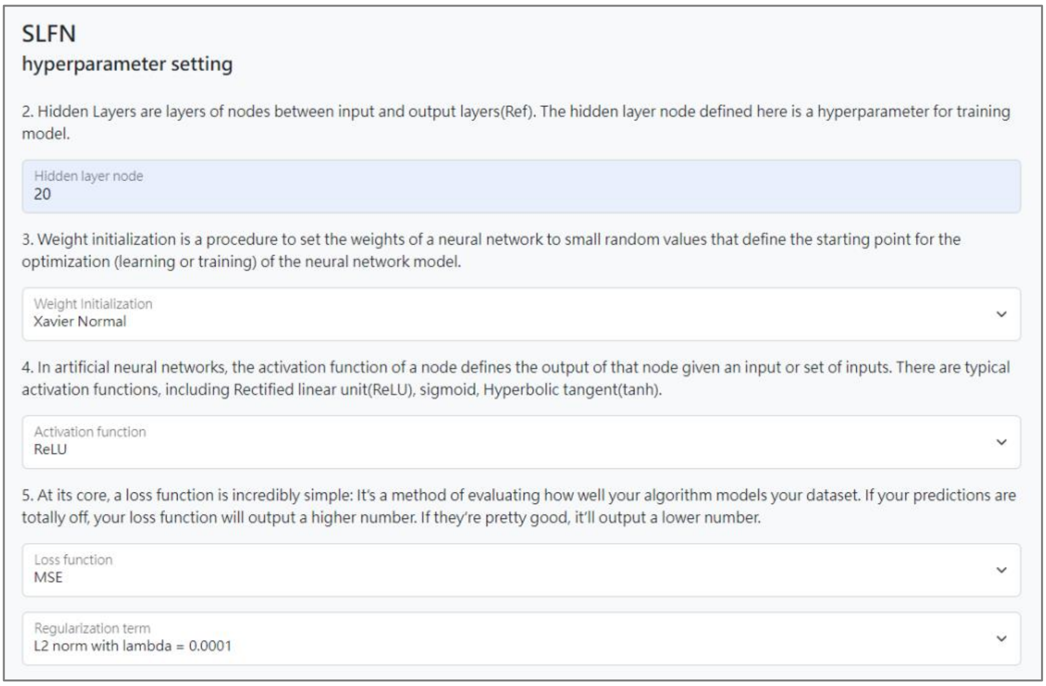

Figure 7 DTF_1-1 on TAaaS_2

- DTF_1-2 and DTF_1-3

Based on the feedback from DTF_1-2 and DTF_1-3, compared to TAaaS_1, in TAaaS_2, we provide an implementation phase flowchart and segment the stages, allowing users to progress step by step through tasks such as data preparation, model training, and model performance.

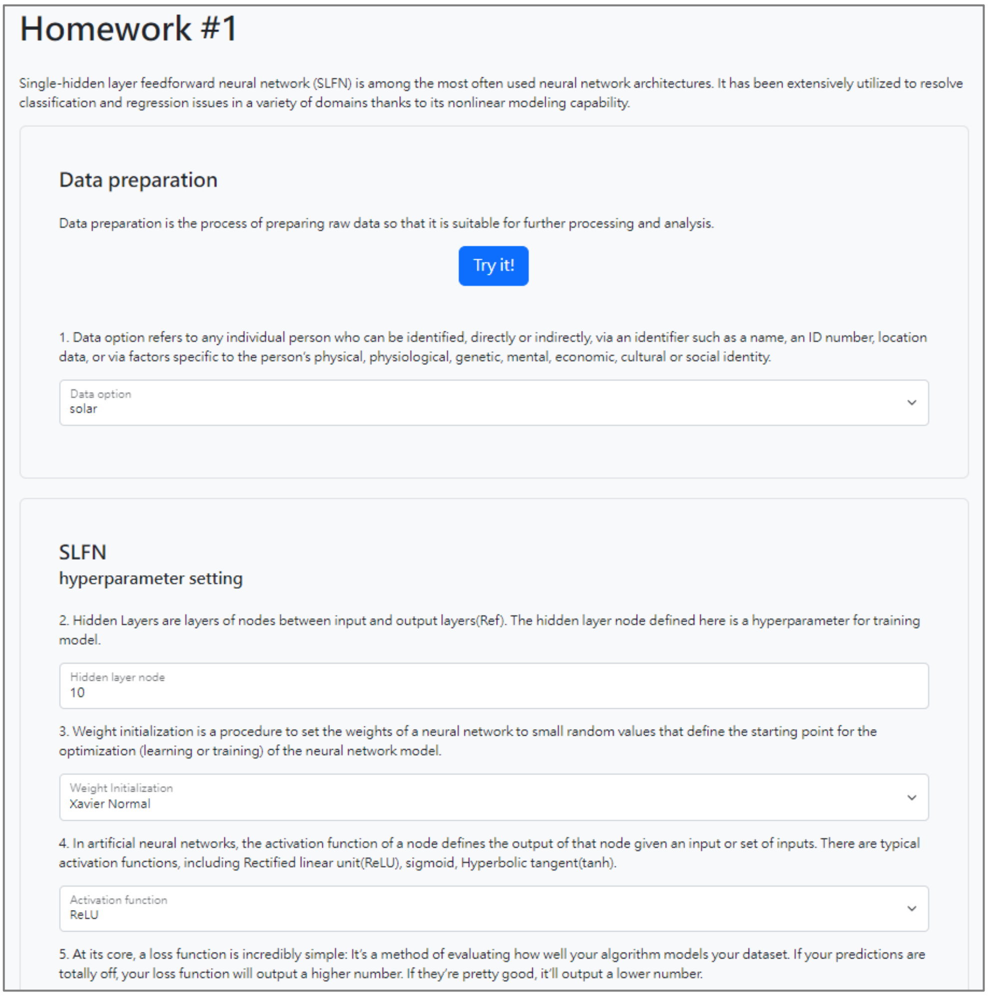

Figure 8 DTF_1-2 and DTF_1-3 on TAaaS_1

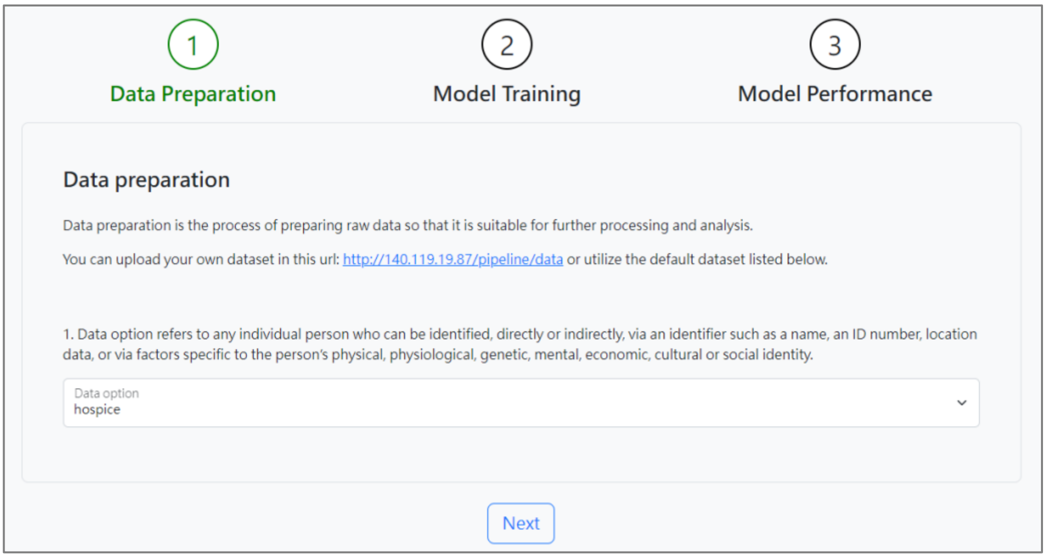

Figure 9 DTF_1-2 and DTF_1-3 on TAaaS_2

- DTF_1-4

Based on the feedback from DTF_1-4, we provide users with the functionality to query the record of model training hyperparameters on the Ensemble page.

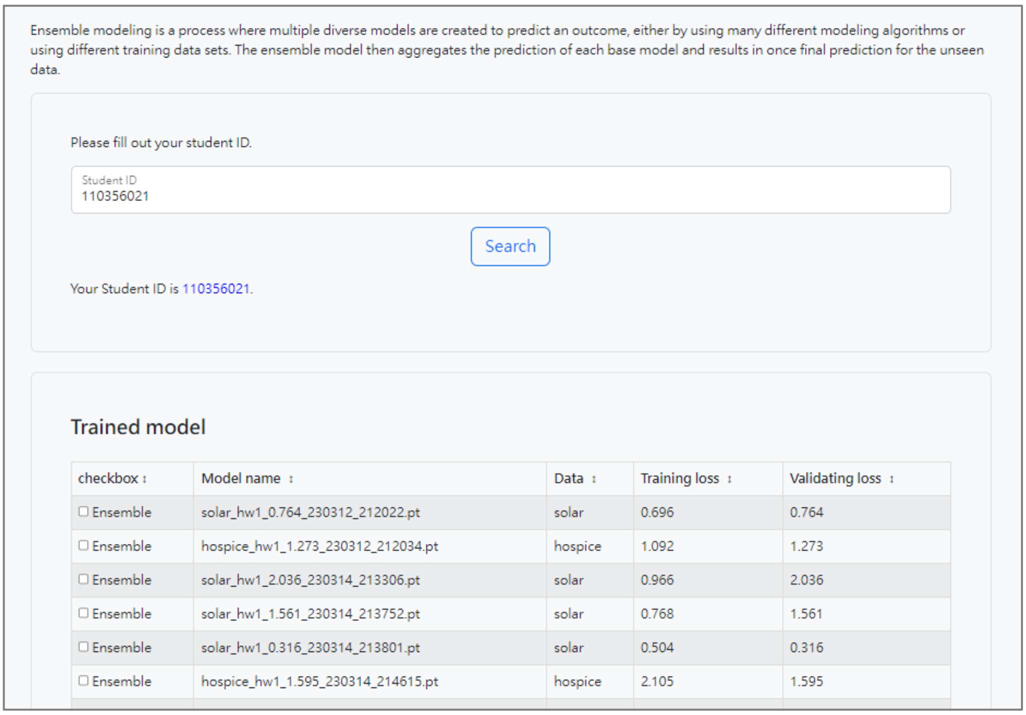

Figure 10 DTF_1-4 on TAaaS_1

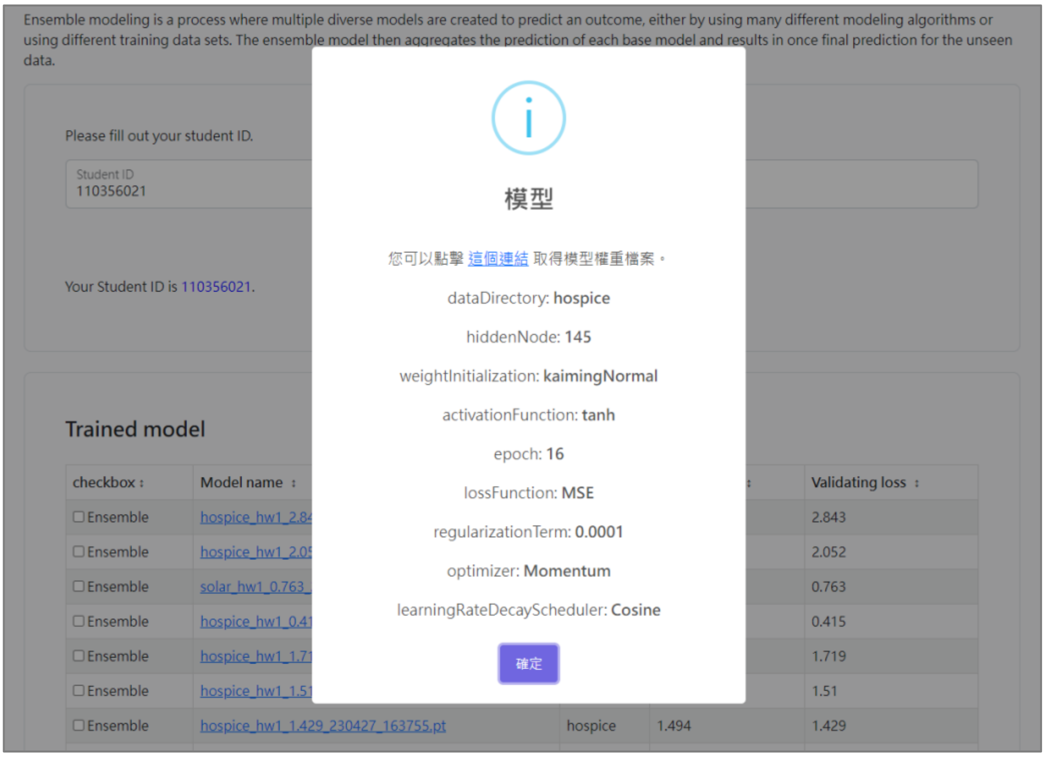

Figure 11 DTF_1-4 on TAaaS_2

- DTF_1-8

Based on the feedback from DTF_1-8, while providing users with the functionality to query the record of model training hyperparameters, we also enable them to download the model's weight storage file (PyTorch file).

Figure 12 DTF_1-8 on TAaaS_2

- DTF_1-12 and DTF_1-13

Originally, the design allowed users to submit code by downloading and uploading files, which would generate new models or modules. After the feedback from DTF_1-12 and DTF_1-13, the required information and method for code submission were designed directly on the web page with a web compiler provided. However, there was no debugging functionality offered.

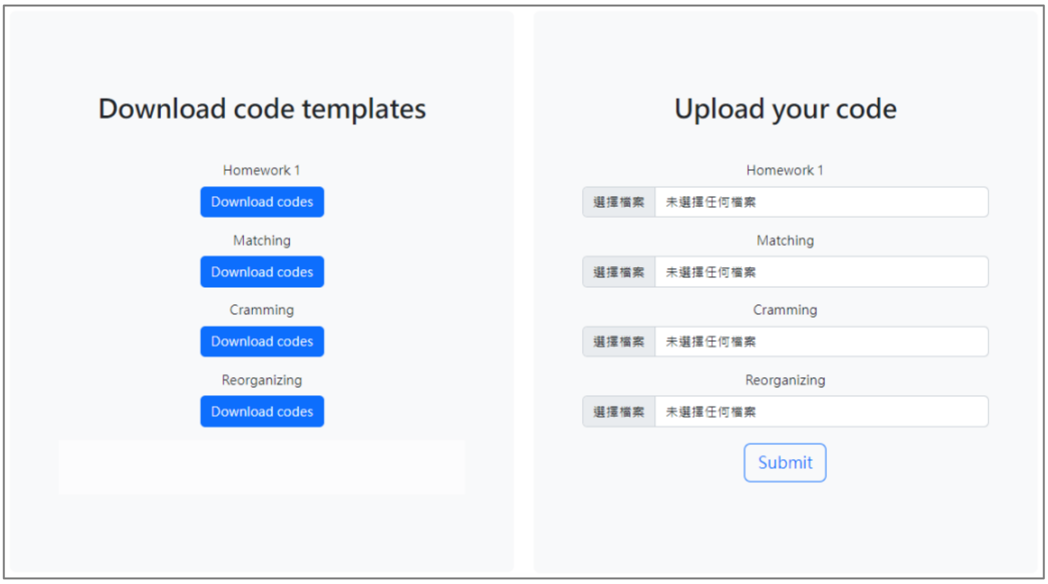

Figure 13 DTF_1-12 and DTF_1-13 on TAaaS_1

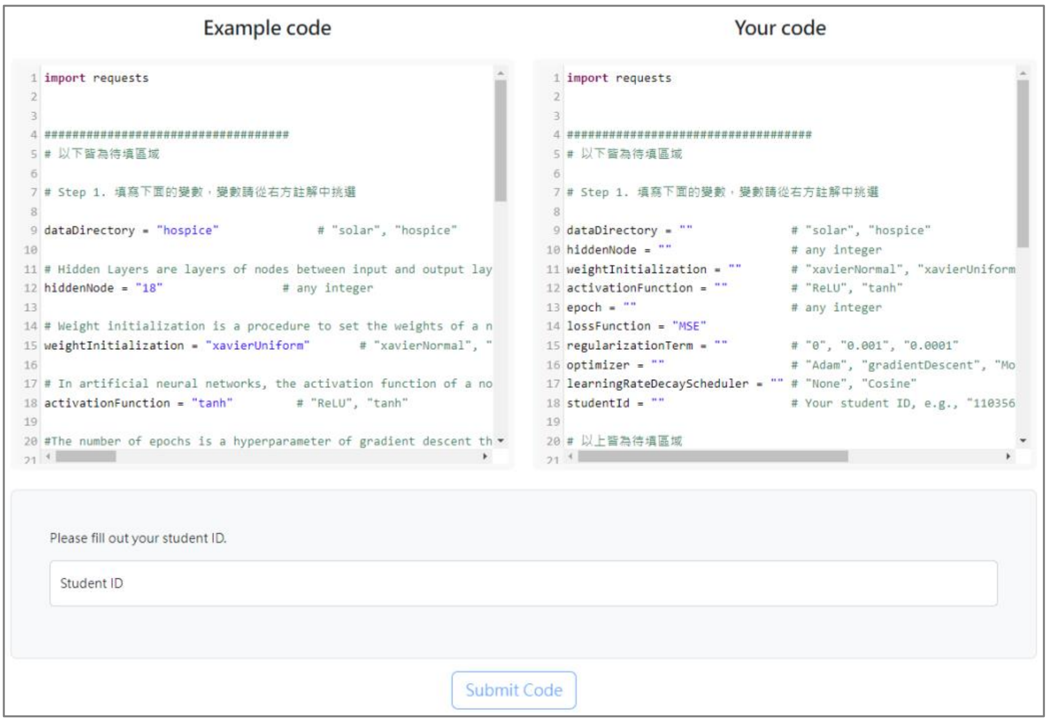

Figure 14 DTF_1-12 and DTF_1-13 on TAaaS_2

5.5. Insight derived from the counter-comparison of the two versions differences

During the initial DTP_1, we conducted the first cycle on TAaaS_1, collecting crucial feedback on user experience and interface issues. Our users point out areas of difficulty, express their needs, and suggest improvements. For example, one piece of feedback (DTF_1–1) suggests the system should retain the user's previous inputs. Responding to this, we modify the web form fields in TAaaS_2 to remember the user's previous data. This modification aims to enhance the user experience by reducing redundant effort and making the process smoother for repeated use. Feedback DTF_1-4 suggests that users need to view model training hyperparameters easily. Therefore, in the TAaaS_2 system, we added a feature that allowed users to query the record of model training hyperparameters on the Ensemble page. This addition makes the comparison and analysis of different model parameters more straightforward for our users. We also receive feedback regarding the mechanism of code submission (DTF_1-12 and DTF_1-13). Originally, users submitted code by downloading and uploading files. Responding to user preferences for a more direct method, we designed the required information and code submission process to be completed directly on the web page. To facilitate this, we incorporate a web compiler into TAaaS_2. However, we also note the lack of debugging functionality in the current setup, which we will consider for future iterations. Another valuable feedback (DTF_1–8) is the need to download the model's weight storage file. In response, we added this functionality in TAaaS_2, allowing users to download the PyTorch file corresponding to the model's weights.

After implementing these design modifications based on the first round of feedback, we run a second cycle: DTP_2 with TAaaS_2. This process allows us to evaluate the effectiveness of our changes and gather more feedback for further improvements. From our experiment, we can know that the TAaaS_2 system, designed based on user feedback from DTF_1, had an impact on the nature of the feedback received during the second DTP_2.

1. Enhanced user satisfaction: Modifications such as retaining user's previous inputs, allowing easy access to hyperparameters, and the provision of a web compiler enhanced the overall user

experience in TAaaS_2. As a result, the feedback in DTF_2 was more focused on improving specific features and streamlining the user interface rather than addressing broader usability issues. This shift demonstrates that the system's usability improved significantly, leading to a smoother and more intuitive user experience.

2. Focused feedback: In the DTF_2, users had fewer fundamental issues with understanding the system or performing tasks. Instead, they suggested enhancements for specific functionalities. For instance, the feedback suggested that the system should provide a button to return to the initial stage of the training process (DTF_2-1), include a section that leads directly to the Ensemble feature (DTF_2-2 and DTF_2-3), and add loss charts to the model links so users can view the training results (DTF_2-4). This shift in feedback represents a more mature stage of system development, where users are more focused on fine-tunings rather than core functionalities.
3. Developer service improvement: Feedback from DTF_2 also suggested that while the overall user experience had improved, there was still room for improvement in the developer section of the service, specifically in making it more user-proof (DTF_2-7). This indicates that while the overall user interface and experience had improved, some areas, like the developer service, needed further attention and improvement.
4. Additional feature suggestions: With the core usability issues largely addressed in TAaaS_2, users had the space to suggest additional features like visualizing loss comparisons and offering back buttons for easier navigation. These suggestions point towards a desire for more sophisticated features that can further enhance the system's utility.

Throughout this study, we utilize an iterative design thinking process to significantly improve the TAaaS system. Starting with TAaaS_1, we obtain vital user feedback (DTF_1) that highlights key areas of improvement for the system's user interface and experience. This feedback drives the design and functionality of TAaaS_2, leading to an enhanced, more user-friendly system that is more closely aligned with user needs.

6. CONCLUSION AND FUTURE WORK

6.1. Conclusion

In conclusion, the implementation and continued fine-tuning of the TAaaS in accordance with the principles of design thinking, has effectively addressed the needs of its users, especially the students in an advanced programming course. This user-centric approach, with its stages of empathizing, defining, ideating, prototyping, and testing, has been fundamental in ensuring that the system is tailored to address user needs, thereby enhancing their overall learning experience. The valuable feedback we gather from users play a vital role in driving enhancements to TAaaS, resulting in a more intuitive and user-friendly system. The features of TAaaS, including the online editor and the ability to remember and review previous training hyperparameters, are greatly appreciated by the users. These features not only streamline the model training process but also provide students with an opportunity to reflect on their strategies and make informed adjustments for future iterations. Moreover, TAaaS has proven to be a practical and convenient tool in training models and understanding hyperparameters. The system's clear instructions and user-friendly interface not only expedite homework completion but also promote a deeper understanding of course material.

In summary, the implementation of design thinking principles in the development of the TAaaS system has shown significant benefits in enhancing the users' learning journey. The iterative, user-centric design process has led to a highly effective, intuitive educational tool, emphasizing the importance of a user-centered design approach in the creation of AI systems.

6.2. Limitation and Future work

The research framework and the TAaaS system have both demonstrated significant potential in their respective domains, despite a few notable limitations. These limitations, coupled with promising directions for future work, serve as a roadmap for the continued fine-tuning and application of both the research framework and the TAaaS system.

- Limitations:
  1. Representativeness, control of variables, and temporal lag influence: In the research framework and the TAaaS system, potential issues with sample size and diversity were identified, which could impact the accuracy and validity of the results. Additionally, controlling variables such as changes in user situations or external environmental shifts posed challenges. A significant consideration is the temporal lag in the system improvement process and feedback collection, which could affect the precision of the outcomes.
  2. System scalability and ease-of-use: In the case of the TAaaS system, scalability is not extensively tested. As the user base and computational demands increase, this might become an issue. Furthermore, the learning curve and initial learning process with the system are not adequately considered.

- Future Work:
  1. Diversity of Feedback and Users: An important direction for future research is to expand the range of user feedback and diversify the user groups involved. This could entail collecting a variety of user feedback for the research framework, as well as engaging a more diverse range of users, including novice programmers or professionals in different fields, in the case of the TAaaS system.
  2. Use of Advanced Technologies: Leveraging advanced techniques like Natural Language Processing (NLP) or Generative Pretrained Transformer (GPT) could

significantly enhance the scientific and efficient analysis of collected data within the research framework. Similarly, for the TAaaS system, incorporating debugging functionality and adaptive learning features that employ AI can yield a more personalized user experience.

3. System Improvements: For the TAaaS system, future research should consider improving scalability and the user interface, especially the Ensemble function, to increase system efficiency and user-friendliness.

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8. APPENDIX

Table 8 Experiment tasks in DTP_1 (Chinese)

- 任務一 - AI Software Service phase
  - 使用個人筆電進入 TAaaS 入口網站，連結: http://140.119.19.87/entry
  - 依照網頁路徑進入 Hw1 的頁面，AI Software Service -> Model pipeline -> Homework #1。
  - 根據頁面上的文字說明，依序填入模型訓練所需的超參數，並訓練出一個模型。注意不必進入 Data preparation 上傳資料集，可以使用系統預設的資料集 (e.g., hospice, solar)。
  - 查看 Model Performance, Training configuration。
- 任務二 - AI Developer Service phase
  - 請用個人筆電進入 TAaaS 入口網站，連結: http://140.119.19.87/entry
  - 進入 AI Developer Service 頁面
  - 下載 homework 1 的範例程式
  - 依照 hw1.py 程式內指示完成步驟
  - 填入所需的欄位
  - 將 hw1.py 壓縮
  - 將壓縮檔命名為 hw1-學號.zip，e.g., hw1-110356021.zip
  - 回到 AI Developer Service 頁面，上傳壓縮檔
  - 進入 Ensemble 頁面，用自己的學號查詢訓練好的模型
- 任務三 - Ensemble phase
  - 請先在 AI Software Service/AI Developer Service 訓練至少 3 個模型，並且在資料集設定使用相同資料集。
  - 進到 Ensemble 頁面，連結: http://140.119.19.87/pipeline/model/hw1/ensemble
  - 用自己的學號查詢訓練好的模型
  - 透過表格的 sorting 功能，查看 Training loss 或 Validating loss 在不同排序下的模型。
  - 選擇前三個訓練較佳的模型，並點擊按鈕送出
  - 查看 Ensemble model 的 validating loss

Table 9 Discussion topics in DTP_1 (Chinese)

1	你認為這個服務頁面提供的資訊是否能引導您完成任務要求的項目嗎? 為甚麼?
2	您認為此服務頁面是否在引導您完成任務要求的項目方面提供了足夠的指導和協助

	？您是否需要額外的幫助或指導才能完成任務？
3	自己寫作業，與透過系統協助完成任務的差異?
4	在自己完成作業時，您會考慮使用哪些系統協助工具？這些工具是如何幫助您更有效地完成任務的？
5	您認為整體使用流程是否順利? 有沒有遇到任何困難或挫折? 有沒有什麼地方使你感到困惑、讓你想要中止使用?
6	根據您的使用經驗，有沒有什麼元素是可以增加在網站內，以幫助您更順利完成任務的?
7	簡短的說一下今天使用完此系統的感受
8	若先使用系統後，再自己完成作業，是否加深學習歷程?

Table 10 Experiment tasks in DTP_2 (Chinese)

- 任務一 - AI Software Service phase
  - 請用個人筆電進入 TAaaS 入口網站，連結: http://140.119.19.87/entry
  - 請依照網頁路徑進入 Hw1 的頁面，AI Software Service -> Model pipeline -> Homework #1
  - 請依照頁面上的文字說明，依步驟完成模型訓練的操作。實驗請使用系統預設的資料集 (e.g., hospice, solar) 即可
- 任務二 - AI Developer Service phase
  - 請用個人筆電進入 TAaaS 入口網站，連結: http://140.119.19.87/entry
  - 請進入 AI Developer Service -> Online Editor 頁面
  - 請依照頁面上的文字說明，依步驟完成模型訓練的操作
  - 若操作順利完成，將會自動導向至 Ensemble 頁面
- 任務三 - Ensemble phase
  - 請使用相同資料集，在前兩個服務中，訓練出三個以上的模型
  - 進到 Ensemble 頁面，連結: http://140.119.19.87/pipeline/model/hw1/ensemble
  - 用自己的學號查詢訓練好的模型
  - 透過網頁上的功能 (例如: 模型訓練資訊、表格排序)，協助您選擇前三個訓練較佳的模型，並點擊按鈕送出
  - 查看 Ensemble model 的 validating loss
  - 實驗結束，請耐心稍等其他受訪者
  - 您可以先將系統使用體驗筆記在提供的文件上

Table 11 Discussion topics in DTP_2 (Chinese)

1	你認為這個服務頁面提供的資訊是否能引導您完成任務要求的項目嗎? 為甚麼?
2	您認為此服務頁面是否在引導您完成任務要求的項目方面提供了足夠的指導和協助？您是否需要額外的幫助或指導才能完成任務？
3	自己寫作業，與透過系統協助完成任務的差異?
4	您認為整體使用流程是否順利? 有沒有遇到任何困難或挫折? 有沒有什麼地方使你感到困惑、讓你想要中止使用?
5	根據您的使用經驗，有沒有什麼元素是可以增加在網站內，以幫助您更順利完成任務的?
6	TAaaS_2 是否有 TAaaS_1 比具備更好的使用體驗?
7	簡短的說一下今天使用完此系統的感受。
8	透過前測中，收取同學們的回饋之後，再改善這個系統，是否更貼近修課同學的需求?

Table 12 Feedback derived from the DTP_1 (Chinese)

Index	Category	Feedback
DTF_1-1	Function	提供欄位記憶和版面停留位置功能，以提高使用者體驗。
DTF_1-2	UI	提供流程圖，以幫助使用者清晰理解整個流程步驟。
DTF_1-3	UI	結構化區塊，包括資料準備、模型訓練和模型績效，以區分不同部分。
DTF_1-4	UI	查看模型訓練超參數的彈跳視窗功能，以方便使用者查看和比較模型。
DTF_1-5	Function	提供 Forward 和 Backward 知識的外部連結，以幫助使用者深入理解模型運作原理。
DTF_1-6	Function	提供資料描述的功能，以更清楚地說明資料集的特徵和屬性。

DTF_1-7	Function	除了損失函數值，也提供模型輸出值，以提供更全面的模型績效評估。
DTF_1-8	Function	可下載模型檔案和程式碼，以便使用者進一步應用和改進模型。
DTF_1-9	Function	提供不同套件之間的使用對照表，例如: Pytorch、TensorFlow，以方便使用者選擇適合的套件。
DTF_1-10	Function	支援多種套件的使用相容性，以增強系統的開放性和靈活性。
DTF_1-11	Function	Ensemble 的背後機制不明確
DTF_1-12	Function	提供更多的文字敘述(註解)，說明超參數用途，以幫助使用者更好地調整模型設計和參數。
DTF_1-13	Function	提供編譯器的擴充功能，以提高使用者編寫程式碼的效率和便捷性。
DTF_1-14	Function	提供編譯器的和 Debug 功能，以提高使用者編寫程式碼的效率和便捷性。

Table 13 Feedback derived from the DTP_2 (Chinese)

Index	Category	Description
DTF_2-1	UI	有一個可以回到訓練步驟初始階段的按鈕，以方便重新訓練模型。
DTF_2-2	UI	在 Entry 頁面提供一個直接進入 Ensemble 的區塊，對應到三項任務的題目。
DTF_2-3	UI	在 Ensemble 頁面提示使用者點選 1~N 個 model 後提交，並增加直接進入 Ensemble 的區塊。
DTF_2-4	Function	在模型連結中加入損失函數圖，以便使用者查看訓練過程的結果。

DTF_2-5	Function	在 Ensemble 頁面中，透過視覺化的介面展示所有或指定模型的損失函數比較圖。
DTF_2-6	UI	在 Online Editor 和上傳下載程式碼的功能中選擇一個呈現方式，避免混淆。
DTF_2-7	Function	在 Developer 版面中加入超參數的防呆功能，例如空值提交時的警示。

Technological Affordance, Motivational Affordances, Emotional Affordances, and Personal Performance: A Conceptual Model for the E-education Affordance Change

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Abstract

Although much research has been done on the affordances and the performance of online users in education. The process of how affordances change online has received little attention. This paper focuses on developing the dynamic process of relationships between affordances and performance. The author argue that the online students perceived the technology affordances at the beginning and then experience motivational affordances and emotional affordances due to the virtual environment changes. Such relationships are strengthened by the time. Meanwhile, the relationships between the affordances and the performances may differ depending on retention time.

Keywords: Affordance Theory, E-education, Technological Affordance, Motivational Affordances, Emotional Affordances, Affordance Change

1. Introduction

The proliferation of computers and the internet has propelled the rapid expansion of e-learning tools and instructional methods. In the 1980s, the advent of personal computers, exemplified by the first Macintosh, spurred the leashing development of e-learning environments over the following decade (Acs et al., 2021). This provided abundant online information and e-learning opportunities, contributing to the growing popularity of online learning (Nicholson, 2007). Technological advancements further reduced the cost of distance learning, facilitating easier access to education.

Simultaneously, businesses actively adopted e-learning for employee training to enhance industry knowledge and skills (Guha, 2017). As of 2021, the total value of the e-learning market reached $315 billion, with an anticipated 20% compound annual growth rate from 2022 to 2028 (Prnewswire, 2022). The online education market is projected to reach $350 billion by 2025, attributed not only to the introduction of flexible learning technologies in corporate and educational sectors but also benefiting from the significant impetus of advanced artificial intelligence-driven platforms on a global scale (Globenewswire, 2019).

Personal performance is a key competency for personal success (Cheng, 2011; Little, 2001; Masud et al., 2019). However, enabling such individual representation in the context of e-learning combines the properties of interactivity and affordance (Wu et al., 2022). The structure of affordances does not stand alone, it depends on elements of the relationship between human actors and technology (Willermark & Islind, 2022). Existing literature has empirically examined the relationship between different affordances and individual performance. However, the results of these studies may look completely changed by other time-series online learning processes. Notably, time-related factors are essential but neglected in terms of individual performance in long-term learning (Cepeda et al., 2008; Yang et al., 2022).

The timescale exhibits dynamic traits in individual performance, encompassing perceptions of both technical and emotional aspects, demonstrating patterns of change over time (Keough et al., 1999). These dynamic traits play a crucial role in online learning environments, directly influencing learners' experiences and academic achievements. Individuals, during the learning process, possess the ability to flexibly switch between different time perspectives based on task features, contextual considerations, and this is regarded as the operation of balancing time perspectives (Jochemczyk et al., 2017).

Time Perspective is conceptualized as a continuous cognitive framework for current experiences and is viewed as a trait when understood as stable, habitual attention to specific time frames (Stolarski & Witowska, 2017). This trait-based temporal viewpoint is subdivided into six factors, including positive past, negative past, present hedonism, present-fatalism, positive future, and negative future (Shipp & Aeon, 2019). The concept is associated with the organizational relevance of these factors with individual performance.

It is noteworthy that individuals can flexibly switch between different time perspectives in learning and work contexts. The flexibility of balancing time perspectives (BTP) has been demonstrated to have a robust positive predictive relationship with subjective well-being (Perman, 2014), which could positively affect performance. Thus, it highlights the profound impact of temporal perspectives on the formation of individual behavior and values.

Previous research has extensively examined the relationship between different affordances (emotional affordances, technological affordances, and motivational affordances) and personal performance. These studies typically conceptualize affordances as relatively one-dimensional concepts. The purpose of affordances is often used in human-computer interaction and is seen as a design guide for reviewing which elements are required in a product (Gibson, 1977). Scholars' partial integration of these real and emotive elements (Norman, 1999) into one concept may eliminate their potential differential effects. Affordances are, in most cases, dynamic interactions with the outside world (Cook & Brown, 1999). Regarding the online environment, research confirms that changes in availability affect online behavior (Zhou, 2021). This suggests that affordance differences arise from combining the material properties of a technology with the intent and awareness of its users, such that the same technology may provide different affordances to different users (Ellison et al., 2015). However, the understanding of the contribution of changes in affordability to individual performance in the specific context of e-education remains limited. Through this study, the author hopes to close this research gap by asking the following research questions:

RQ1: *What is the effect of a technological affordances on motivational affordances and emotional affordances, and how does time moderate these relationships?*

RQ2: *What is the effect of motivational affordances and emotional affordances on personal performance, and how does time moderate these relationships?*

RQ3: *What is the effect of technological affordances on personal performance, and how does time moderate this relationship?*

To answer the research question, the author implemented a new model. Previous research on motivational needs has argued that the way in which basic individual needs are met in technological design increases user interaction and usage (Tang & Zhang, 2019), a state of ease of use that inspires beneficial adaptive experiences for success (Sheldon et al., 2001). Therefore, the author argue that technological affordances can promote motivational affordances. The author then use a public health lens to examine the impact of technological affordances on emotional affordances (Chen et al., 2021). The author hypothesize that perceptions of technology being entirely useful and practical can lead to positive and robust responses to emotional affordances. The manifestation of emotion over time has been documented as a key condition of salient motivation (Cheng, 2014). The author then argued that the more emotional affordances that are present, the more motivational affordances are present, and that time strengthens this relationship. Furthermore, convincingly, the author combine several different pieces from the previous literature to test the proposed complex relationship between affordances and individual performance. The author reasonably assume that these affordances are somehow related to individual performance. The author also find evidence for changes in affordance over time in the ecological psychology literature. (Heft, 2018) states that features of the environment can have alternative affordances at different times in different encounter contexts. Affordance is a temporary intuitive phenomenon. The effects of time are not homogeneous, but depend on the extent to which individuals identify with various features of the technology. While many studies have focused on distinct elements and unique samples of a single affordance study, the novelty of the study lies in its integration of multiple elements and their subtle interactions (**Table 1**).

In Table 1, the author summarizes that some scholars confirm that technological affordances are the inherent capabilities and advantages offered by digital tools or technologies that influence an individual's learning experience and personal performance (Li & Pow, 2011; Mao, 2014). Additionally, motivational affordances are the features within a learning environment or task that stimulate an individual's motivation, including elements that spark interest, present challenges, or offer rewards (Jong, 2014; Pellas & Kazanidis, 2014). Furthermore, emotional affordances are the opportunities and capabilities of a learning context or technology to evoke and impact emotional experiences, such as satisfaction, frustration, enjoyment, or a sense of accomplishment during the learning process (Cheng, 2014; Morie et al., 2005; Roblyer & Wiencke, 2003).

Table 1. Literature on Affordances in E-education

Author	Affordances		
	Technological	Emotional	Motivational
Krouska et al. (2022) (Krouska et al., 2022)	X		X
D'Ambra et al. (2022) (D'Ambra et al., 2022)	X		
Wu et al. (2022) (Wu et al., 2022)	X		
Hwang et al. (2021) (Hwang et al., 2021)	X		X
Carless et al (2022) (Carless, 2022)	X		X
Pechenkina et al. (2017) (Pechenkina et al., 2017)	X		X
Comer et al. (2015) (Comer et al., 2015)		X	X
Mao (2014) (Mao, 2014)	X		
Pellas & Kazanidis (2014) (Pellas & Kazanidis, 2014)			X
Cheng (2014) (Cheng, 2014)		X	
Jong (2014) (Jong, 2014)			X
Lim et al. (2012) (Lim et al., 2012)		X	X
Xu & Moloney (2011) (Xu & Moloney, 2011)			X
Li & Pow (2011) (Li & Pow, 2011)	X		
Morie et al. (2005) (Morie et al., 2005)		X	
Roblyer & Wiencke (2003) (Roblyer & Wiencke, 2003)		X	
Conole & Dyke (2004) (Conole & Dyke, 2004)	X		
This Study	**X**	**X**	**X**

Specifically, Krouska et al. (2022) investigated the technological affordance of Mobile Game-Based Learning (MGbL) during COVID-19. Results showed that MGbL positively leveraged mobile devices to influence technological affordance. Wu et al. (2022) emphasized the pivotal role of technology affordances and constructivist learning in the success of e-learning. Xu & Moloney (2011) explored interactive whiteboard (IWB) pedagogy in tertiary education, revealing the positive impact of IWB on character retention, students' learning experience, and motivation. Li & Pow (2011) examined the impact of one-to-one tablet-PC implementation on student learning, finding positive effects on both formal and informal learning. Morie et al. (2005) explored emotional affordance in virtual environments (VE), focusing on manipulating sensory and emotional aspects to understand the emotional affordances in VE. Roblyer & Wiencke (2003) discussed the challenge of defining measurable interaction quality in distance learning environment, aiming to enhance understanding of interaction's role through the development of standards.

Furthermore, Krouska et al. (2022) found that MGbL positively influenced motivational affordance, enhancing student engagement and performance in programming. Carless (2022) emphasized the importance of digital affordances, peer review, and examples in effective feedback, highlighting the role of students as the center of the feedback process. Pechenkina et al. (2017) investigated the impact of a gamified mobile learning app on student engagement and academic performance, implying technological and motivational affordance. Cheng (2014) explored emotional affordance in a MOOC, revealing altruistic emotion fostering collaboration and intergenerational emotional resonance. Jong (2014) found positive impacts of LearningVillages (LV) on collaborative knowledge building (CKB) among elementary students. Lim et al. (2012) proposed an Emoticon Support Tool for emotional affordances in computer-mediated communication to enhance online collaborative learning.

Some research implies affordances based on the use of specific tools. Mao (2014) investigated high school students' capacity and attitudes towards social media for learning, emphasizing the need to optimize social media's affordances in education. D'Ambra et al. (2022) applied affordance theory to explore e-textbook engagement in the digital transformation of higher education, highlighting the importance of considering affordance dimensions to enhance participation and usage. Comer et al. (2015) explored both positive and negative aspects of Massive Open Online Courses (MOOCs) for teachers and students, pointing out challenges in managing negative emotions in MOOCs. Hwang et al. (2021) delved into the evolution of mobile learning in higher education, identifying key research clusters and underlining the significance of mobile technology affordance. Conole & Dyke (2004) discussed the challenge of defining measurable interaction quality in distance learning courses, aiming to enhance understanding of interaction's role through the development of standards.

In the remainder of this study, the author review the literature on affordance theory, develop proposed propositions and conceptualize the ideas. In addition, the author conducts a quantitative analysis of the literature to clarify the variables used in the model. Finally, the author summarizes the students' e-learning process.

2. The Affordances Theoretical Perspective of Variability

Although historically, affordance was viewed as an immutable property of the object that gave it its functionality, it is perceived by users based on their individual needs (Gibson, 1977). Since then, Norman formally proposed the concept of perceptual affordance (Norman, 2004). Perceptual affordances in human-computer interaction (HCI) have been extensively discussed in many educational studies (Blewett & Hugo, 2016; Hafner & Candlin, 2007; Hammond, 2010). In education and IS research streams, affordance is often associated with the use of technology (John & Sutherland, 2005).

The apparent variation in affordances is due to situations where the interaction between the technology and the environment has to be handled through the behavior of the user (Ugur et al., 2009). It is worth noting that the emergence of technology itself does not produce changes in affordability (Wang & Cranton, 2014). This is a dynamic process related to perception and action processes (Raymond et al., 2017). Leonardi (2013) found that users use different affordances depending on their goals, and that affordances may change when groups of users pursue their goals in the same technological space (Leonardi, 2013). Variations in this affordance can explain how users express their intuition about technical systems and reflect how they use properties in the system in different contexts and moods.

The author can affirm that the several of studies on the temporal scale of blended learning are conducted within the context of specific learning platforms. These platforms serve not only as places for information exchange but also as community spaces where learners gather to share knowledge and experiences. Through these platforms, learners can interact, exchange opinions, and, at the same time, the educational esthetes provided by the platform influence their learning experiences. In the field of e-education, changes in availability are associated with shifts in activity characteristics (Wan, 2010). As can be seen in Table 2, the existing literature explores the affordances-change view of affordance theory over time scales. In the case of knowledge transfer, the dynamics of affordances are easily observed (Cook & Brown, 1999). Inconsistent messages generated by users can lead to changes in the control of transmitted information and knowledge (Wan et al., 2008), which can lead to changes in affordances. Affordance dynamics are experiential changes that affect interaction frequency over time (Augustsson, 2010).

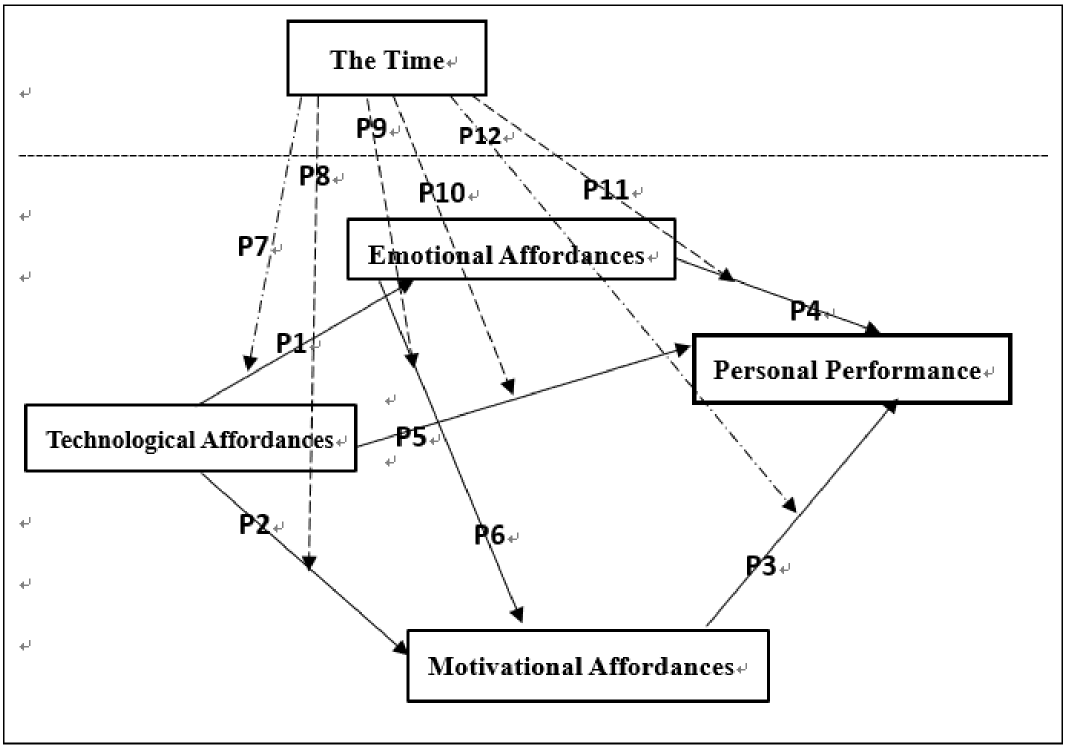
Table 2. Review the Evidence on Changes in Availability over Timescales

Restheces	Findings
Chen & Li (2022) (Chen & Li, 2022)	The time scale affects the user's perception of system uncertainty, which in turn affects performance goals.
Kligler-Vilenchik et al. (2020) (Kligler-Vilenchik et al., 2020)	Over time, online users dropped out of the debate as the content of the forums became frustrated.
Chen et al. (2018) (Chen et al., 2018)	Due to the large number of clues generated by time, the user's uncertainty in using the system will be reduced, resulting in a pleasant experience.
Pibernik et al. (2019) (Pibernik et al., 2019)	The interaction between the user and the system changes over time resulting in differences in the download experience.
Acosta (2016) (Acosta, 2016)	E-education users take advantage of the flexibility of distance learning to increase their knowledge, efficiency, and resthecefulness over time.
Bang et al. (2014) (Bang et al., 2014)	The degree of dispersion of consumption and purchase time affects the difference in purchasing behavior of online consumers
Liikkanen & Gómez (2013) (Liikkanen & Gómez, 2013)	The user's subjective feelings about the passage of time caused by the system will produce different experiences of behavioral use.

3. Proposition Development

In the study, the author performed secondary data analysis. In this section, the author reviews the literature on e-learning based on affordance theory and propose the following propositions. Finally, the author develops the research framework based on the proposal (Figure 1).

Figure 1. Framework



Proposition I : The technological affordances are positively related to emotional affordances (P1).

Technological affordances expresses the possibility of action, that is, what can be accomplished by individuals or groups working towards a certain goal using technology or information systems (Majchrzak & Markus, 2012).

Technological affordances are often linked to levels of availability (Norman, 1988). Conversely, without basic ICT skills, it is difficult to actually use the technology (Bobsin et al., 2019). In most cases, availability is associated with cognitive processes that can be triggered by emotional affordances (Norman, 2002). Creating a sense of connectedness in the technical support area can lead to emotional support (Zhou et al., 2022). Badia et al. (2011) state that "technological affordances should not be viewed as...inherent in technological characteristics...they are inherently dynamic" (Badia et al., 2011), p. 32). A study mentions that the emergence of usability in technology affordability is seen as an important mechanism influencing emotional interaction in e-learning (Kirschner et al., 2004). The usability of technology is primarily related to what happens at the human-machine interface ((De Souza & Preece, 2004). The human-computer response can be seen as the behavior of the optical illusion cyborg (Haraway, 2006). A well-designed ability to use technology increases students sense of control and belief in value (Artino Jr & Jones II, 2012). When students learn online, "emotional arousal" is always present (Wosnitza & Volet, 2005).

In short, proposition I illuminate the dynamic interplay between technological affordances and emotional responses, emphasizing their integral role in shaping the online learning experience, where a sense of connectedness and emotional arousal are constant companions.

Proposition II: The technological affordances are positively related to motivational affordances. (P2)

According to Abd-Mutalib et al. (2019), motivational affordances occur concurrently with activities that provide gamification (Abd-Mutalib et al., 2019). Chen et al. (2018) further classify motivational affordances into votes and badges, serving as criteria for internalization into intrinsic motivation, thereby keeping online users engaged and helping them achieve their goals (Chen et al., 2018). Previous studies have delved into antecedents of motivational affordances such as scoreboards and game rewards (Liu et al., 2017; Ofosu-Ampong & Boateng, 2020). It is noteworthy that while motivational affordances vary across different gamification scenarios, users' actual actions commence after the perception of motivational affordances (Deterding, 2011). The utilization of gamification in e-education is highlighted, as it puts students into a state of flow (Urh et al., 2015). Gamification is considered a mechanism for providing feedback and interaction (Huotari & Hamari, 2011). Furthermore, gamification serves as an evaluation of the "compatibility" of new technologies (Bíró, 2014). In most cases, the lower the usability, the less likely it is to be gamified. Issues related to usability accelerate users' perception of gamified systems as less interesting, consequently having negative effects on users, such as motivation (Rajanen & Rajanen, 2017).

This proposition emphasizes the interplay between technological and motivational aspects in a gamified environment, suggesting that the application of gamification in e-education may positively impact student engagement and goal achievement.

Proposition II underscores the intricate interplay between technological and motivational elements in gamified environments, highlighting the potential positive impact of gamification in e-education on student engagement and goal achievement.

Proposition III: The motivational affordances are positively related to the personal performance of the students (P3).

Users' goals and inclinations affect individuals' incentive performance (Rockmann & Maier, 2019), which in turn affects the individual's final performance. People need instantaneous reactive feedback control in the process of goal achievement, resulting in a relative state of psychological disequilibrium, which is related to motivating personal skills (Bandura, 1993). Feedback is an effective and useful tool in e-education to improve understanding of performance and goals through comparison (Kluger & DeNisi, 1996; Serge et al., 2013). In the educational context literature, gamification is recognized as a potent tool that can serve as a motivational factor, creating a link to the motivational affordances experienced by learners, consequently influencing their overall performance. The integration of gamification elements, such as rewards, badges, and interactive challenges, has been shown to effectively engage students and contribute to a positive learning environment. This motivational aspect, deeply rooted in gamification principles, plays a pivotal role in shaping students' attitudes, behaviors, and ultimately, their academic outcomes. Gamification is a mainstream of research on motivational affordances (Kay J et al., 2006; Rambusch & Susi, 2008; Weiser et al., 2015), which drives value creation for users (Huotari & Hamari, 2012). Gamification provides motivation to empower participants (Zhao & Tang, 2016). On the other hand, the better outcome of motivational affordance is that the individual maximizes the function in the system (Schick et al., 2016), which is closer to improving individual performance. The motivation process through the gamification approach of goal realization is a dynamic chain of events rather than a single event (Chou, 2019; Zhao & Tang, 2016).

In short, proposition III (P3) is to understand motivational dynamics. The proposition delves into the intricate dynamics between motivational affordances and students' personal performance. This understanding is fundamental for educators as it provides insights into what motivates students and how these motivations translate into academic success.

Proposition IV: The emotional affordances are positively related to the personal performance of the students (P4).

In general, previous work has considered the relationship between affectively relevant affordances and representations (Cid & Núnez, 2014; Holmberg, 1994; Zembylas & Vrasidas, 2004). Cheng (2014) studied the role of emotional affordance in e-education and found that positive emotions can lead students to a fearless educational experience (Cheng, 2014). Erdoğdu & Çakıroğlu (2021) found that students who perceived humorous emotions had improved task comprehension and possibly improved performance (Erdoğdu & Çakıroğlu, 2021). Jiao et al. (2021) found that visibility into IT systems had a positive impact on emotional perception and motivation (Jiao et al., 2021).

In conclusion, Proposition IV holds significance by contributing to the advancement of the comprehension regarding the intricate interplay between emotional affordances, encompassing positive and humorous emotions, and its impact on student performance.

Proposition V: The technological affordances are positively related to the personal performance of the students (P5).

The purpose of technological affordances in e-education is to assist in information sharing during the decision-making process (Cordes, 2016). Decisions have a direct impact on performance (DuBrin, 2013). When technology availability is elastic, high performance outcomes are easily observed (Cabiddu et al., 2014). In a sense, the availability of technological affordances can express perceived utility in a system. Wang et al. (2016) identify updatable, differentiable displays as important factors of technology affordability and making it easier to present results for achievement (Wang et al., 2016). Therefore, the author think students will be more aware of the ease of use of the system, which is a core element of technology affordability. The more technological affordances are present, the higher the individual performance is reflected.

Proposition VI: The emotional affordances are positively related to the motivational affordances (P6).

Individuals' perceived emotions provide intrinsic and extrinsic motivation (Jiao et al., 2021). Emotional affordances unfold experiences and exhibit phenomena entangled with technology and environment to motivate motivation (Bareither & Bareither, 2019). Emotions are motivators that drive and guide behavior (Zhang, 2008). The nature of emotion in e-education is forced to arouse in a self-directed manner to motivate action (Wosnitza & Volet, 2005). In addition, positive emotions generated by previous successful e-educational task experiences lead to positive motivation (Lai & Chen, 2016). Thus, the author argue that students' interactions with technology use and the environment become more intense, triggering the emergence of emotional affordances that influence changes in behavior (i.e., motivational affordances).

Proposition VII: The length of time moderates the relationship between technological affordances and emotional affordances such that the greater length of time provided, the stronger the impact of technological affordances on emotional affordances (P7).

Over time, it becomes easier for people to use, and then technological affordances take root (Gaver, 1991). Haines (2015) found that online students tend to master and perceive functions after a longer period of time, showing latent active emotions (Haines, 2015). In the case of usability issues, comments posted by online users appear wildly out of sync, making it difficult to truly express emotion (Sutcliffe et al., 2011). Thus, the author argue that online systems act as intermediaries between individuals and other users, with negative effects on individuals' perceptions of system availability blurred over time. If students perceive affordances to be low, this negative effect can cause emotional affordances to be hidden over time, but it is also possible that users get used to this affordances and thus emotional affordances keep emerging.

Proposition VIII: The length of time moderates the relationship between technological affordances and motivational affordances such that the greater length of time provided, the stronger the impact of technological affordances on motivational affordances (P8).

Kappen et al. (2017) demonstrated that after cultivating ease of use of technology and then developing the habit of providing feedback over time, users drive the power of intrinsic and extrinsic motivation (Kappen et al., 2017). Furthermore, the relationship between technology and motivational affordance is similar to joint demand in economic theory (Jarrahi et al., 2018). Online users' understanding and use of technology evolves over time, reflecting a new perception of motivation to learn (Haynes, 2014). On the other hand, users show only an initial impression of what the technology has to offer, but respond differently to motivational affordances over time (Jia et al., 2016).

In summary, Proposition VIII not only highlights the temporal evolution of user habits but also establishes parallels with economic theory. Additionally, it recognizes the dynamic nature of user perceptions and their long-term responses to motivational affordances.

Proposition IX: The length of time moderates the relationship between emotional affordances and motivational affordances such that the greater length of time provided, the stronger the impact of emotional affordances on motivational affordances (P9).

Individuals stabilize over time and reappraise the task (Suri et al., 2018), which affect shifts in motivational affordances. In most cases, individuals add appraisal mechanisms to adjust their emotional affordances over time according to existing circumstances and possibly set their ongoing motivational affordances (Beltman & Volet, 2007). Simultaneously, behaviors interact with emotions as humans perceive positive or negative emotions in virtual environments over time (Lin et al., 2017). Meroli et al. (2014) noted that online users experience emotional release and exhibit narrative effects of affordance after individuals engage in online environments over time, which may lead to different motivational changes (Merolli et al., 2014).

In summary, Proposition IX is important because it sheds light on the temporal evolution of individuals' perceptions, emotions, and behaviors in virtual environments. This understanding is instrumental for tailoring educational interventions to support adaptive motivation and positive experiences over time.

Proposition X: The length of time moderates the relationship between technological affordances and personal performance such that the greater length of time provided, the stronger the impact of technological affordances on the personal performance of the students (P10).

The relationship between technological affordances and performance is malleable over time (Gibson et al., 2022). Features of visibility, persistence, and editability in systems positively impact individual creative performance (Sun et al., 2020). Several studies have shown that the relationship between technology provision and performance is related to knowledge acquisition (Lehrer et al., 2018; Sun et al., 2020; Vuori et al., 2019; Xiangming & Song, 2018). Ali-Hassan et al. (2015) found that the pathway from technological affordances to performance varies with social factors (Ali-Hassan et al., 2015). Chen & Li (2022) found that the more obvious the temporal cues, the clearer the understanding of task completion (Chen & Li, 2022). Given enough time, users can become familiar with the use of the technology and perceive its ease of use.

Proposition XI: The length of time moderates the relationship between emotional affordances and personal performance such that the greater length of time provided, the stronger the impact of emotional affordances on the personal performance of the students (P11).

Gamification builds learners' sense of achievement through reward systems and level advancements. This aligns with the individuals' needs, as per the Theory of Affordance, for achievement and reaching goals. The establishment of a sense of achievement can inspire learners' enthusiasm and commitment. This association may change over time. Information from real-time data leaderboards improves student performance over time (Chapman & Rich, 2018). Gamification approaches can help increase long-term motivation (Saputra & Risqi, 2015), thereby improving individual performance. Over time, game mechanics create fatigue and reduce student engagement, which reduces their performance (Faiella & Ricciardi, 2015). Thus, the author argue that over time students can develop a sense of solidity about the system that can be viewed as the emotional affordances that lead to individual differences in performance.

Proposition XII: The length of time moderates the relationship between motivational affordances and personal performance such that the greater length of time provided, the stronger the impact of motivational affordances on the personal performance of the students (P12).

Emergence of emotions occurs in the moment, but emerges socially and iteratively (Boiger & Mesquita, 2015). This discovery will provide a stimulus for individual performance. Over time, students' emotions build up in the classroom to become self-examination, which affects their individual performance (Varelas et al., 2022). Emotional stability is associated with personal achievement (Correia et al., 2012; Jia et al., 2016). Therefore, the author believes that over time, students may receive more homework and work in teams, resulting in higher motivating abilities, which will be reflected in individual performance levels

Considering these observations, this proposition posits that an extended temporal horizon, coupled with strategic interventions like increased homework assignments and collaborative teamwork, cultivates heightened motivational abilities. This cultivation, in turn, translates into elevated levels of individual performance.

4. Affordance Literature Analysis

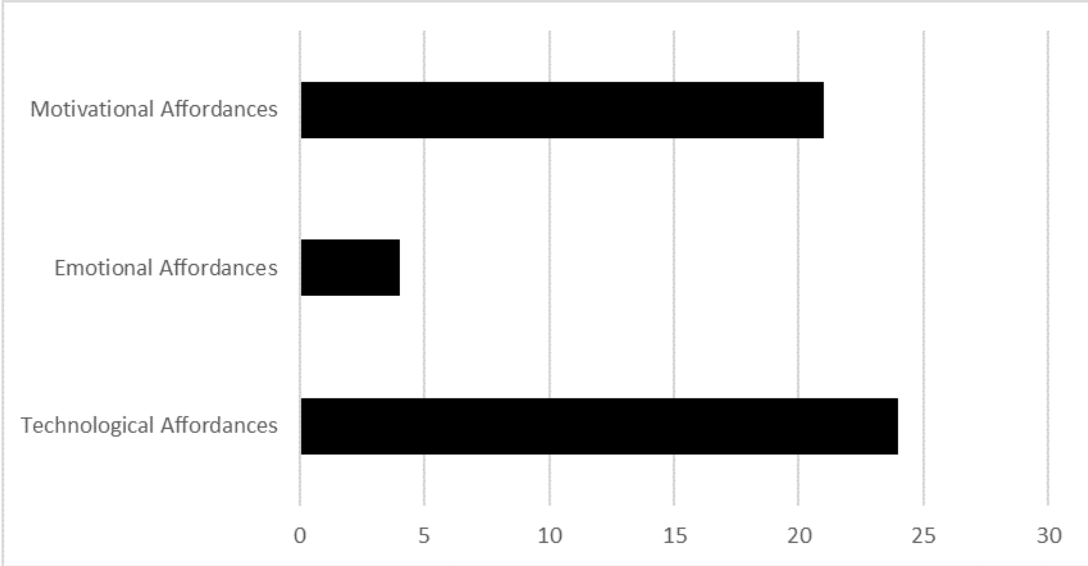
To identify the research variables in the research framework, the author analyzed articles on affordance theory. The author screened articles containing affordance theory from information management journals. The journals the author analyzes include:

1. Decision Support Systems
2. Communications of the Association for Information Systems
3. Electronic Commerce Research and Applications
4. European Journals of Information Systems
5. Information & Management
6. International Jthenal of Human-Computer Studies
7. Information Systems Frontiers
8. International Journals of Electronic Commerce
9. Information and Organization
10. Journals of Strategic Information Systems
11. Journals of Management Information Systems
12. Journals of Information Technology
13. Journals of Organizational Computing and Electronic Commerce
14. Journals of the Association for Information Systems
15. Organization Science
16. The Information Systems Journals

From 2016 to 2023, the authors selected 49 articles for analysis. In this section, the research will disassemble the affordance factors highlighted in each article, drawing from individual affordance theory. These studies are associated with e-learning to provide a specific angle for comparison. Previous affordance research has covered education, organizational behavior, and online communities. Most affordance research focuses on technological and motivational attributes (Figure 2). Specifically, 24 studies

(49%) were technology-related. 21 studies (43%) were about motivation. 4 studies (8%) were about emotions.

Figure 2. Affordances Research Topic Distribution (Number)



The author examined the distribution of related emotional affordance studies (Figure 3). The results concluded that 3 studies (75%) highlighted both positive and negative aspects related to emotional affordance. Van Vugt et al. (2006) investigated user interactions with game interface characters, viewed affordances as having positive and negative dimensions (helping and hindering), and found that users tend to use helpful characters rather than hindering characters (van Vugt et al., 2006). Lee et al. (2021) argue that interactions between gamers and gaming platforms are often associated with experiencing positive emotions or reducing negative emotions (Lee et al., 2021). Wang (2020) defines affordance as emotion regulation, studying how communication media tools affect emotions (facilitate or suppress) (Wang et al., 2020). Additionally, 1 study (25%) focused on health aspects. James et al. (2019) Consider affordances as extroverted and introverted exercise goals using the example of bodybuilders (James et al., 2019). Individuals may have a negative relationship with data sharing in health devices (introverted exercise goals), users may worry about anxiety (privacy), and use health tools less.

Figure 3. Focuses Distribution for Emotional Affordance Theory's Research (Number)

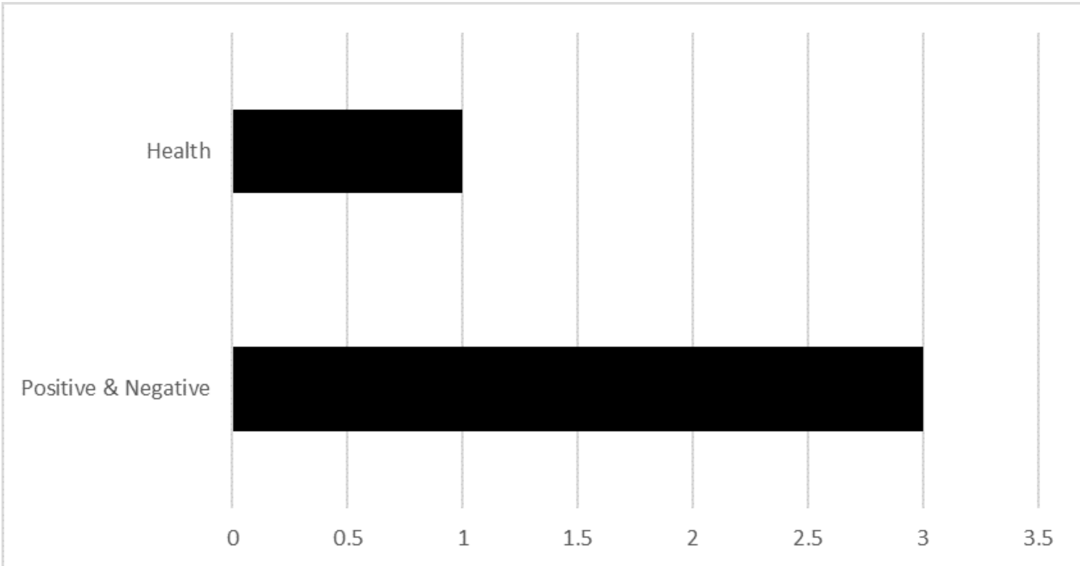
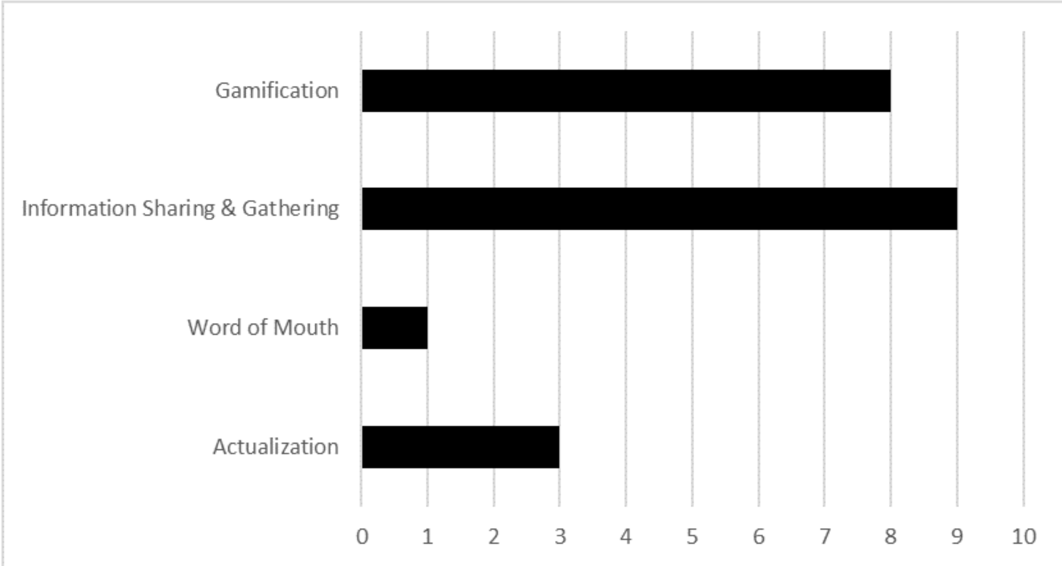


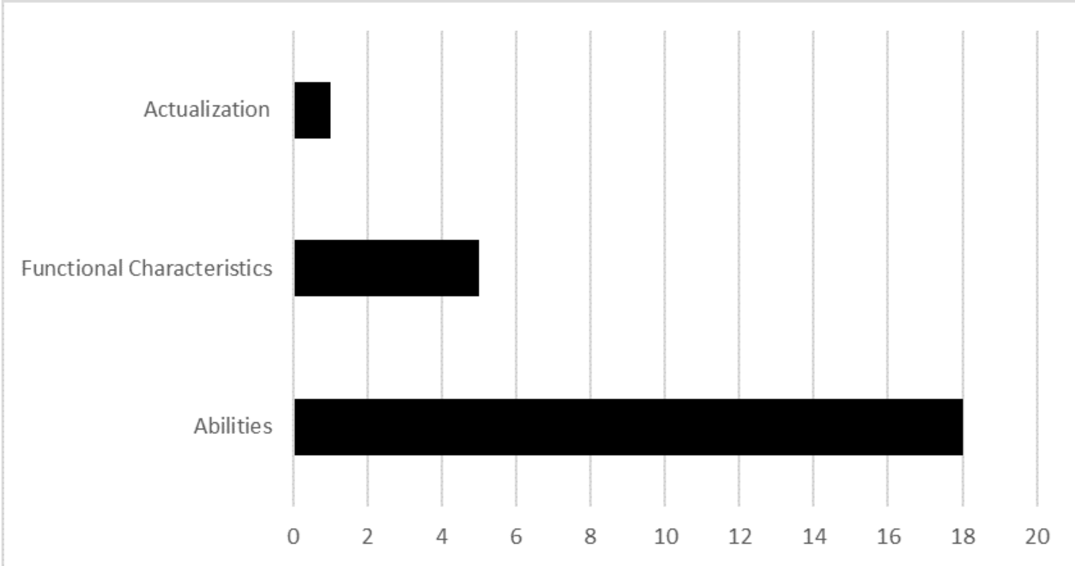
Figure 4 lists the various motivational affordance types. Previous research revealed 4 motivational affordances: information sharing and gathering (n = 9, 43%), gamification (n = 8, 38%), actualization (n = 3, 14%), and word of mouth (Lin et al., 2019) (n = 1, 5%). This suggests that motivational affordances are often revealed through information exchange and collection (Chatterjee et al., 2021; Eismann et al., 2021; Goel et al., 2013; Herterich et al., 2022; Leidner et al., 2020; Leonardi, 2017; Malhotra et al., 2021; Waizenegger et al., 2020; Zheng & Yu, 2016). The purpose of information exchange is often for collaboration, allowing users to express their opinions through the platform (Eismann et al., 2021). Sometimes, users get more resources and perform more social activities during information exchange (Leidner et al., 2020). On the other hand, users interact with interfaces and achieve goal motivation through gamification (Benitez et al., 2022; Chen et al., 2019; Koroleva & Kane, 2017; Lavoué et al., 2021; McKenna, 2020; Suh et al., 2017; Tan et al., 2017; Wang et al., 2022). Gamification maturity requires effective use of rewards (Suh et al., 2017; Tan et al., 2017). Scholars often use voting and badges as gamification indicators of motivation affordance (Chen et al., 2019; Koroleva & Kane, 2017; Lavoué et al., 2021). The motivational affordances of these 3 studies focus on the possibility of realization (Dremel et al., 2020; Henningsson et al., 2021; Thapa & Sein, 2018). Dremel et al. (2020) investigate the reliability of data-driven services (Dremel et al., 2020). Thapa & Sein (2018) explored the implementation of perception in virtual environments (Thapa & Sein, 2018). Based on the above, the author argue that online platforms' feedback mechanisms (as basic functions of information exchange), badges, and voting can measure online students' motivational affordances.

Figure 4. Focuses Distribution for Motivational Affordances Theory's Research (Number)



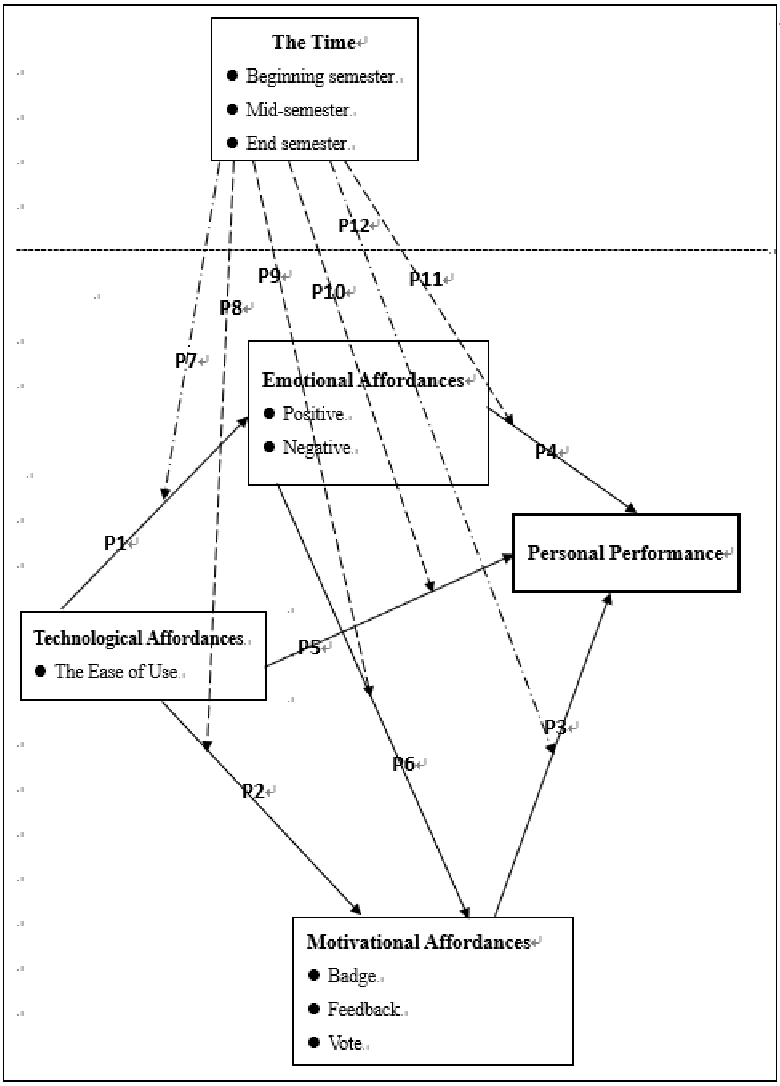
In terms of technological affordances research (Figure 5), previous studies have revealed three different categories of technological affordances: (1) actualization (Tim et al., 2020). (2) functional characteristics (Knote et al., 2020; Lei et al., 2021; Prakasam & Huxtable-Thomas, 2021; Still & Dark, 2010; Sun et al., 2023). (3) abilities (Argyris & Monu, 2015; Chan et al., 2019; Chatterjee et al., 2020; Chatterjee et al., 2017; Chen et al., 2021; Dincelli & Yayla, 2022; Du et al., 2019; Fang, 2019; Findikoglu & Watson-Manheim, 2016; Hatakka et al., 2020; Lehrer et al., 2018; Miao et al., 2022; Osmundsen et al., 2022; Sheer & Rice, 2017; Sun et al., 2019; Thapa & Sein, 2018; Van Osch & Cthesaris, 2017; Zahedi et al., 2022). Scholars most commonly refer to technological affordances as the ability of individuals to use technological devices. 18 studies (75%) were about technology availability in relation to capabilities. Technology availability represents the potential of IT to function in a collaborative organizational environment (Chatterjee et al., 2020). Fang (2019) extended technological affordances to the context of brand applications, proposing five affordances: visibility, persistence, interactivity, relevance, and selectivity (Fang, 2019). When IT elements are applied to the design of a virtual environment, an individual's exposure to personally relevant capabilities within that environment results in affordance (Zahedi et al., 2022). Second, 5 studies (20.8%) were about technological availability of functional features. Sun et al. (2023) defined affordance as symbolic language and found that the influence of symbolic language and content ideology on opinion polarization has a positive moderating relationship (Sun et al., 2023). It is critical to consider content ideology and symbolic expression when evaluating polarized opinions online. Lei et al. (2021) investigated the impact of different types of information technology and different functions on the diversification of different businesses, taking the logistics industry of 23 cities in China as an example (Lei et al., 2021). To sum up, when the user's ability to master technology improves, it also represents the ease of use between the user and the technical equipment to a certain extent.

Figure 5. Focuses Distribution for Technological Affordances Theory's Research (Number)



While these articles were not specifically focused on personal performance in online learning, their aim is to enhance performance, considering factors such as continued use or intention. According to the analysis of the research questions in the past literature, the author believe that technological affordances essentially represents an easy-to-use relationship between users and systems. The higher the ease of use, the higher the functionality and performance of the system functions to the user. The emotional affordance expresses the immediate impression of the user's perception of the system. In the field of e-education, students either reflect a happy positive attitude or develop a boring negative learning attitude. Positive and negative is therefore the most straightforward dichotomy for emotions. Motivational affordances reflect the index to measure whether the user stays in the system further, and in the context of online learning, the relevant game functionality will become the main variable of motivational affordances. In terms of time, school students participate in courses and then use online platforms, usually in one semester (about half a year). Therefore, it is assumed that novice students will use the platform at the beginning, mid-courses (assign task bombing) and end of semester (project acceptance). the process can make a difference in the response to the different affordances. Based on the above, the following is the operational model of this study (Figure 6).

Figure 6. Research Model



Conclusion

This paper helps to address previous concerns that the nature of affordance is dynamic and should be categorized and assessed in the development of each educational scenario (Badia et al., 2011). In the study, the idea behind the conceptual model is that affordance's changes as online users' retention on the platform increases and teachers' expectations of students become visible over time. Existing IT impact research literature shows that the capabilities of technology can provide users with impressions that can be perceived as value (Markus & Silver, 2008). The key evidence emerging from the existing literature is that users can perceive affordances in the context of information delivery and can increase and decrease the strength of affordances (Burlamaqui & Dong, 2015). These arguments lead to the perspective on affordance in the context of e-education. The role of affordance in e-education is sequential and nested (Hammond, 2010). The author expects online students to initially perceive more technological availability due to lack of skills and knowledge. Such technological affordances change with the evolution of time, and users learn to use them subtly, and their reliance on the ease of use of technological affordances may be reduced, gradually forming an emotional impression on the platform. Users are assigned online tasks and have to learn the online system, otherwise they will not be able to complete the target tasks, which will affect personal performance (i.e., grades). The author argue that users switch synchronously from technological affordances, users perceive emotional affordances (e.g., positive, negative, neutral) because users develop some emotional thoughts about technology when it is useful or not. It's as if they were plugged into an outlet to generate electricity.

Meanwhile, when teachers encourage some teamwork at the start of the semester, users move on to more motivating features. Over time, users learn about this virtual environment, their classmates, and teachers, so they develop more motivational or emotional affordances. This finding is consistent with studies by Camilleri (2012) and Taipale (2014) [Ref (Camilleri, 2012; Taipale, 2014)], in which users generate associated affordances as a result of perceiving properties that are integral to technology and form habits over time, thereby lead to solidification of practice. The author conclude that individual performance levels arise from temporal differences in the interaction between technological function perception and the virtual environment. To the knowledge, this is the first attempt at such a framework. In conclusion, this paper will help us better understand the mechanisms that lead students to incorporate technology into their learning behaviors over time.

In addition, the affordances will eventually reflect a relationship between individuals and the object, and often the quality of this relationship will be reflected in performance as a measure of Human-machine interaction's design. When the affordance is explicit to be observed, it will strongly induce the emergence of personal performance, producing superior or inferior outcomes. This also means that each affordance in the model will be linked to individual performance.

The author firmly believe that this framework can elucidate the distinctive affordances elements encountered by each learner at various stages, offering valuable insights into the nuanced dynamics of user behavior. By doing so, the contribution extends beyond the realm of e-education, providing essential foundations for human-machine design. This understanding of the diverse challenges and preferences experienced by learners throughout their educational journey is instrumental in tailoring interfaces and experiences that align with individual needs and enhance overall engagement and increase performance.

5. Research Limitation

Despite the valuable insights gained from this study, it is essential to acknowledge certain limitations that may impact the generalizability and applicability of the findings. Firstly, the focus on e-education contexts, while providing a rich understanding of the dynamics within this domain, may limit the generalizability of the proposed framework to other educational settings. Educational environments with different modalities, structures, or technological infrastructures may exhibit unique affordance patterns.

Secondly, the reliance on retrospective analysis and qualitative methods for data collection poses limitations on the establishment of causal relationships. Future research endeavors could benefit from employing longitudinal studies or experimental designs to better ascertain the cause-and-effect relationships between affordances, time dynamics, and personal performance.

Additionally, the proposed framework assumes that affordances evolve over time, impacting individual performance. While this assumption aligns with existing literature, variations in individual learning styles, preferences, and external factors might introduce complexities not fully accounted for in the current model.

Furthermore, the generalization of findings to diverse learner populations, considering factors such as age, cultural background, and prior experience with technology, should be approached with caution. The nuanced interplay between these variables and affordance dynamics warrants further exploration.

Lastly, the study focuses on the affordances within the e-education landscape but does not extensively delve into social affordances. The exclusion of social affordances represents a limitation, and future research could explore their role and impact in greater detail.

In conclusion, while this study contributes significantly to understanding affordance dynamics in e-education, researchers and practitioners should interpret the findings within the outlined limitations and consider these aspects in the design and interpretation of future studies.

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