ORIGINAL ARTICLE

Motivational assistance system design for industrial production: from motivation theories to design strategies

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Abstract
Industrial production is still widely sustained by human operators. However, the design of human–machine interaction often does not foster the motivation to learn more about their machine or system. This may decrease operators' ability to flexibly adjust their decision making and problem-solving skills to the current production context. Motivation to learn could be attained by a motivating socio-technical design of assistance systems, but suitable and context-specific design strategies are lacking. In the present study, a systematic literature review of motivation theories in education, at the workplace, and in system design was carried out. The resulting 16 theories were integrated into a conceptual model of motivating assistance system design in industrial production. In this model, learning motivation results from the satisfaction of the needs for autonomy, competence, and relatedness, which in turn is mediated through the design of the system (including interface, task, and behavior). Moreover, this process is subject to moderating influences from job characteristics, personal variables, and factors concerning the respective work domain. Strategies for motivational design are derived from the model, and an example from the discrete processing industry is used to illustrate how the model could be applied to design assistance systems in this domain. Finally, the procedures for theory selection and model development are discussed, theoretical and practical implications are derived, and alternative strategies of instilling motivation are considered.

Keywords Motivation · Assistance systems · Motivation and technology · System design · Workplace learning · Learning strategies

1 Introduction

Industrial processes are becoming increasingly more automated (Hancock 2013) and modern cyber-physical production systems can use large amounts of connected data across different components of a plant (Lasi et al. 2014). This highly flexible connectivity opens up new possibilities for production processes. Still, fully automated production is far beyond the reach and thus human operators remain an essential part of industrial systems (Nelles et al. 2016; Parasuraman and Wickens 2008). In different work domains, the task of operators is to keep processes within operational limits and intervene during faulty behavior (Müller and Oehm 2019; Wang et al. 2015). To do so in the flexible environment of cyber-physical production systems, operators need to adjust their decision making to the current production context (Hirsch-Kreinsen 2014; Müller and Urbas 2017). This also requires them to learn about different production contexts and transfer this knowledge between contexts (Müller 2019). Such learning could be fostered by assistance systems that convey information about the system state and its causal relations, past problem cases, and possible solutions. The relevance of educational technology in industrial contexts has been recognized for many years (e.g., Mavrikios et al. 2013) and previous work has already suggested to use assistance systems as digital learning environments for Industry 4.0 (e.g., Prinz et al. 2017). The implementation of such systems needs to be based on domain models, learner models, and paedagogical models (Ullrich 2016). Moreover, learning can be supported by a use of innovative technologies such as smart glasses (Spitzer et al. 2018). However, an essential prerequisite to learning that is often neglected in technology-centered approaches is the motivation to learn

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(Pintrich 1999). In many contemporary work environments, motivation cannot be taken for granted, and operators often lack the motivation to learn more about their machine or system (Schult et al. 2015).

Motivation can generally be defined as "any internal process that energizes, directs, and sustains behavior" (Reeve 2016, p. 31). Motivation theories have been researched and applied in different areas such as education, finance, work, and game design (Hussain et al. 2007; Kanfer et al. 2007; Sailer et al. 2017; Shellnut et al. 1999). These theories help understand why people act in a certain way, what drives their behavior towards personal or shared goals, and how this knowledge can be used to direct actions in a desired way. However, until now no theory exists which adequately supports the development of strategies and methods to design assistance systems in ways that instill or increase motivation to learn.

1.1 Why does motivation to learn matter?

In industries that rely on the operation of advanced technologies, the motivation to learn is of utmost importance as performance in these settings depends on operator skills and knowledge (Adler 1988; Walton and Sussman 1987). In spite of this, almost a quarter of the industrial sector employs unskilled workers who have received no formal training and therefore mainly use procedural skills and shortcuts instead of domain knowledge to solve problems (Hirsch-Kreinsen 2016; Müller and Oehm 2019). Therefore, it is crucial that operators learn about their machines while performing their job, and such learning should actively be supported. Earlier work suggests that this pays off. For instance, in one study (Wall et al. 1990) operators of CNC machines were provided with the knowledge and autonomy to diagnose and correct minor faults by themselves instead of relying on specialists. This intervention led to a reduction of downtime of up to 70%, from 150 to 26 min in an 8-h shift (Jackson and Wall 1991). In a reanalysis of the data, Jackson and Wall (1991) investigated the causes of this performance improvement. They found that the intervention did not change the time it took to fix a fault but strongly reduced the frequency of faults. This indicates that operators learned how to prevent faults from occurring in the first place. Thus, learning about their machines enabled them to operate them in a proactive manner.

Learning will become even more important with the advent of cyber-physical production systems, due to their high flexibility. For instance, in modular plants it is possible to change the physical plant setup to meet current demands. This means that the plant that an operator is facing today may have other characteristics than the one he or she operated yesterday. Imagine that a reactor module is exchanged for another one with a different heating principle (e.g.,

pumping steam through a jacket vs. using a heating coil). In this case, it is important to understand how the heating principle affects the process, because different operation strategies may be required (e.g., accounting for different heat transfer rates, preventing local hotspots). This poses high demands on operators' ability and motivation to learn (for an overview see Müller 2019).

1.2 Prerequisites for assistance systems that support motivation to learn

In principle, cyber-physical production systems provide ample opportunities to support learning: Given their processing capabilities and the availability of large amounts of data, appropriately designed assistance systems could serve as digital learning environments. In this way, they could make learning an integral part of operators' daily work. This is not something contemporary human–machine interfaces typically accomplish. Oftentimes, they make large amounts of data available to operators without giving them direct control to use this information. In consequence, operators have little incentive to continuously absorb and interpret the data (Hirsch-Kreinsen et al. 2018).

Instead, interfaces should be designed in such a way that their use does not pose excessive demands on operators' cognitive capabilities. According to Sweller's Cognitive Load Theory (Sweller 1988; Sweller et al. 1998), this can be achieved by minimizing the amount of extraneous load (i.e., the cognitive load produced by the instructional design itself) and promoting germane load (i.e., cognitive processes that are fundamental for the construction of schemas). Additionally, Mayer and Moreno (2003) describe different ways of reducing cognitive load in multimedia learning such as eliminating redundancy, filtering out interesting but extraneous material, providing pretraining, and off-loading some essential processing from the visual to the auditory channel. To improve performance, the operator cognitive load should be optimized. This optimization can be achieved by avoiding workload redlines which refer to the points on the supply and demand space of cognitive resources where operators are approaching or exceeding their tolerances for performance (Young et al. 2015). The authors also suggest that cognitive load may be reduced by automating parts of a task, extensive training, or reassignment of tasks to another operator. In the case of cognitive underload, demand may be increased by increasing the difficulty of a single task. Moreover, Van Acker et al. (2018) underline the importance of emotional load in their explanatory framework of mental workload. This load affects the allocation of mental resources during the presentation of cognitive work demands, which are then appraised either positively or negatively. In addition, the authors incorporate the process of schema acquisition from Cognitive Load Theory (Sweller 1988), which focuses

on the long-term acquisition of knowledge. Taken together, these concepts emphasize the importance of work and instruction design as well as cognitive load optimization to improve performance. However, while they are an essential prerequisite for learning, they do not guarantee that operators will actually be motivated to learn. Therefore, the design of human–machine interfaces should actively contribute to instilling or sustaining motivation (Hancock 2013).

1.3 Towards designing motivational assistance systems

Up until recently, motivational effects in Human Factors and industrial settings have largely been neglected due to the presumption that operators already are motivated or that a lack of motivation could be compensated using purely organizational measures (Szalma 2009, 2014). In the last few years, theories have emerged that try to explain how motivation can stem from the design of systems or interfaces and from the user's interaction with these artifacts (Peters et al. 2018; Szalma 2014). The present article builds upon former theories to theoretically integrate concepts of learning motivation with concepts of motivation originating from Human Factors and system design. To this end, motivation theories from three application areas are considered: education, the workplace, and system design.

At its core, motivation to learn is closely related to research on motivation in education. Theories in this area try to find answers as to why people are motivated to learn and what factors drive and sustain learning motivation. However, learning in an industrial environment introduces additional constraints for learners and learning materials. Therefore, theories on motivation at the workplace are considered to find out what motivates people to strive towards a shared goal in the context of an organization, and what factors might hinder or constrain learning success in these environments. Lastly, the devices and systems used to achieve the goals defined in educational contexts and at the workplace have motivating qualities of their own. These qualities should be taken into account when developing strategies for motivating assistance systems in industrial production. Therefore, the third research area is motivation in system design.

The objective of the present article is to (1) collect and integrate motivation theories from these different areas, and (2) build on these theories to develop a model of motivational assistance system design. Thus, we use a theory-driven approach to derive practical strategies that system designers can use to create assistance systems which help increase operators' motivation to learn more about their machine or system. To this end, we take five steps. First, we extract and discuss the main elements and constructs of motivation theories from the three application areas. Second,

we compare the core elements of different theories in an endeavor to theoretically integrate them. Third, we combine these elements into a model of motivational assistance system design in industrial production (MADIP). Fourth, we derive practical strategies for design and present an example of how to apply them. Finally, we discuss possible implications and provide an outlook for future research.

2 Method

To develop strategies of motivational assistance system design, different motivation theories from three major application areas were gathered: motivation in education, at the workplace, and in system design. To accumulate a set of relevant theories in these areas, a systematic literature search was carried out between May and July 2019 using the databases Web of Science, MEDLINE/PubMed, as well as PSYNDEX and PsycINFO via EBSCOhost. No time frame was given and results were searched in English and German. The search strings *TI*(*work* OR education* OR learn* OR industr**) *AND TI motivat* AND* (*theor* OR framework OR model OR design OR approach*) and (*system* OR "assistance system" OR design**) *AND motivat** and *TI*((*motivation**) *AND* (*design OR human factors*)) *AND theory* resulted in 8886 research papers. Due to the fact that motivation research in the field of system design is a rather new topic and specific theories are not represented as well as in the other two fields, we decided to broaden the search string to include theories on Human Factors in general that mention motivation in the title. The resulting papers of all search strings were combined into a single file in the *bibtex*-format, which was then processed using BibTex Tidy (West 2019), removing 1710 duplicates. The remaining 7119 papers were imported into BibDesk (McCracken and The BibDesk Team 2017) to further structure them.

In the first step, papers were grouped according to the three application areas. This was done using the BibDesk *Smart Group*-feature in combination with an additional global search string. Papers on motivation in education were identified by filtering *education AND motivation* in the keywords as well as (*academ* OR educat* OR learn* OR class**) *AND motivation** in any field, resulting in 284 papers. Papers on motivation at the workplace were identified if the keyword section contained *work* AND motivation* and any field matched the string (*work* OR employ* OR job OR occupation* OR organization**) *AND motivation**, which returned 125 papers. Finally, papers on motivation in system design were identified via keywords that contained *design AND motivation* in combination with the search string (*computer OR engineer* OR mobile OR online*) *AND* (*learn* OR assist* OR mediat* OR train**) *AND motivat** in any field, which resulted in 125 papers as well.

In the second step, we identified those papers that were concerned with either creating or applying a theory on motivation. Every group created in the previous step was therefore filtered with *theor** and the resulting abstracts were analyzed. This step produced a total of 15 theories on motivation in education, 21 theories on motivation at the workplace, and nine theories on motivation in system design.

In the third step, we counted how often individual theories occurred in the selected papers. Based on the resulting counts, we decided to include every theory with five or more occurrences for further analysis. The cutoff was set because we aimed to include theories that were applied in at least a few different settings and also provided possible strategies that could be incorporated into the model. We considered this to be important to achieve the goal of defining a model which can be useful for practitioners and designers. The cutoff resulted in an inclusion of ten theories on motivation in education and ten theories on motivation at the workplace. Due to the fact that research on motivation in system design is a relatively new branch of motivation research which has produced much fewer theories than the other application areas (Szalma 2009, 2014), we decided to keep all nine theories for further analysis, even if their number of occurrences was lower than five.

In the fourth step, the 29 theories were individually searched using the four databases mentioned above. Search strings were the name of the theory in combination with *empiric* OR appli* OR valid** to identify supporting evidence for the theoretical assumptions. A theory was included if there were (a) at least three papers from different authors that empirically validated the theory and (b) any number of papers that applied specific strategies in relation to that theory. These criteria were chosen because in step four we specifically looked for empirical validation of those theories we had identified as being broadly applied across domains in the previous step. We, therefore, argue that this procedure

best narrowed down the space of theories by identifying those that were applied in different contexts by different authors with the possibility of deriving application strategies. Step four resulted in a total of 16 theories: five theories on motivation in education, seven theories on motivation at the workplace, and four theories on motivation in system design. While researching further literature on the application of these theories, it turned out that five of them were used in a variety of different areas, so that allocating them to only one of our three areas would not have been appropriate. Therefore, these more general theories are considered as an individual category in the present review. Accordingly, our final sample consists of five general theories, four theories on motivation in education, three theories on motivation at the workplace, and four theories on motivation in system design.

Due to the fact that the above search terms were targeted specifically at *motivation* as a keyword, the final model does not include theories such as the Technology Acceptance Model (Davis 1989), its integration into a gamification framework (Herzig et al. 2015), the Theory of Planned Behavior (Ajzen 1991) or the Theory of Reasoned Action (Fishbein 1976). While all these theories deal with some kind of motivated action or behavior towards a technology, they are not primarily concerned with motivation and were therefore not included. Implications of this choice are detailed in the discussion.

To derive a theoretical model, the 16 theories were visually clustered according to the four major areas of education, the workplace, system design, and general theories. Figure 1 provides an overview of these theories. In the next step, the individual constructs of the theories were analyzed using the factor descriptions of the original articles. Major recurring themes were then clustered and colored in the overview graph. Additionally, theoretical connections between different theories were drawn
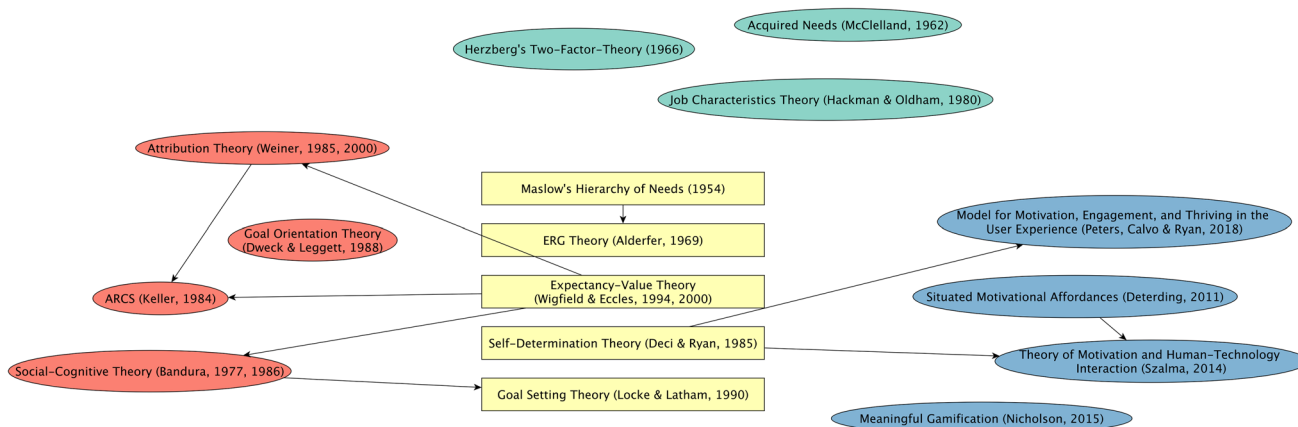

Fig. 1 Overview of theories including their relations. The boxes in the center of the figure represent general theories that apply to different areas. Round shapes represent theories in the areas of education (left), workplace (top), and system design (right)

either if one theory preceded the other or if factors of one theory were directly used in or adapted from factors in another theory. Next, it was investigated whether each of the recurring themes could be matched with a theory which best represented its contribution regarding the overall goal of learning motivation. For instance, need satisfaction as a recurring theme was best represented using the needs defined in Self-Determination Theory (SDT; Deci and Ryan 1985) due to its large body of evidence and the contexts it has been applied to. The theories emerging from this examination were then integrated into a final model on motivational assistance system design in industrial production (MADIP). This integration focused on the practicality and possible application scenarios of the final model, which should allow for its direct implementation in various work domains. For instance, the flexibility that is enabled by the layer design of the model for Motivation, Engagement, and Thriving in the User Experience (METUX; Peters et al. 2018) was used to make the integration of different theories possible, and the Job Characteristics Model (JCM; Hackman and Oldham 1980) was included due to its readily available diagnostic tools. Furthermore, the ARCS Model of Instructional Design (Keller 1987) and the concept of meaningful gamification (Nicholson 2015) were not integrated as individual model factors but rather used as two sets of strategies which have been shown to be successful in achieving motivation in different settings and domains. The MADIP model was then used to derive possible strategies, which are illustrated using a hypothetical example.

3 Motivation theories

In the context of industrial assistance systems that motivate operators to learn, three areas of motivation should be considered. The first is motivation in education because instilling motivation to learn is a core aspect of theories from this area. Educators have long been concerned with different ways of making learning material interesting and motivating. However, operator tasks in industrial production are embedded in a complex interplay of factors that differ from those in educational settings. Such factors must be taken into account when designing motivating assistance systems. Lastly, operators' specific tasks mostly involve interactions with technological devices or systems, and the motivational effects of these artifacts should be investigated. Before presenting motivation theories developed in these three areas, we first consider a number of general theories that have been applied in a variety of contexts and thus cannot be allocated to any specific area.

3.1 General motivation theories

The majority of the theories we found can be allocated to one of the three areas described above. However, some theories have been applied in more than one area or in different contexts altogether. Their concepts span the presence of innate needs, the expectancy of success, the setting of goals, as well as intrinsic motivation. Figure 2 provides an overview of these theories by visualizing their components, and Table 1 summarizes their key concepts.

3.1.1 Expectancy-Value Theory

Expectancy-Value Theory posits that motivation is influenced by the extent to which people feel a personal importance or intrinsic interest in doing the task and by the extent to which they believe that the wanted result will follow if they try. Therefore, actions are driven by an expectancy of success combined with the subjective value of executing a task (Eccles et al. 1983; Wigfield and Eccles 2000).

Differences in expectancy and value are observable in children, adolescents, and adults. Eccles et al. (1993) assessed how young children perceived their competence in different activities and how they valued these activities. They found distinguished self-beliefs. This indicates that even young children have clear beliefs about what they are good at and what they value (Wigfield and Eccles 2000). Such differences in success expectancy and perceived task value are still observable in adolescents and adults. Hood et al. (2012) analyzed factors that affect psychology students' attitudes toward statistics. Students who believed that studying was easier and who displayed positive feelings about the subject were more likely to attach importance to statistics and to indicate positive success expectancies regarding their future, which in turn may lead to better achievement. These results underline the importance of not only taking into account subjective beliefs about succeeding in a task but also the value of this task.

3.1.2 General Needs Theories

Some of the most prominent needs-related theories propose that human beings are driven by the desire to satisfy certain innate needs. Maslow's Theory of Human Motivation (1954) posits the existence of a hierarchically structured set of needs that are common to all human beings. If lower-order needs such as *physiological* or *safety* needs are satisfied (e.g., the individual has enough food and is sheltered and warm), it strives to satisfy the next set of needs, namely *belongingness and love*. These are followed by *esteem* needs (i.e., the desire for a high evaluation of oneself), which in turn are followed by *self-actualization* needs (i.e., the need to fulfill one's unique potential). The different needs are not
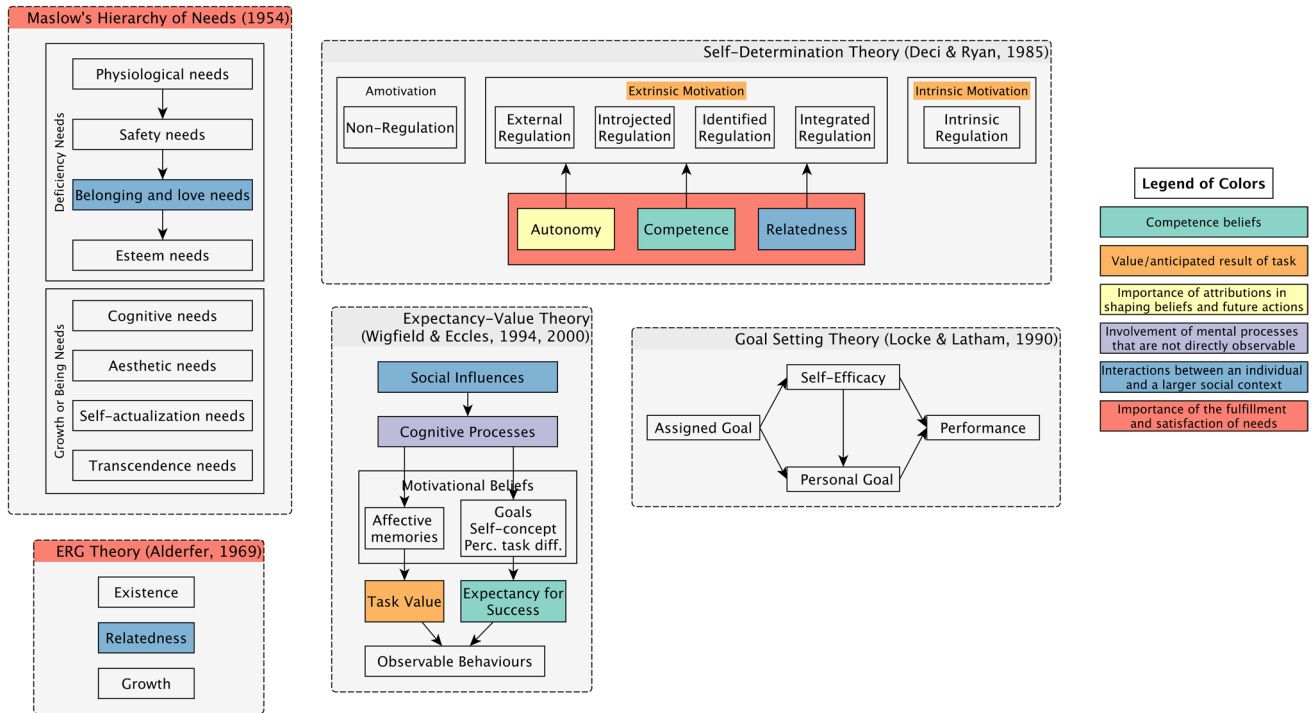
Fig. 2 Overview of general motivation theories. Where available, adaptations of the original model structures were used, otherwise a new model representation was created in such a way that all models fit on the page

Table 1 Overview of general motivation theories

Theory and authors	Concepts
Expectancy-Value Theory (Eccles et al. 1983; Wigfield and Eccles 2000)	Expectancy for success combined with the subjective value of executing a task drive actions. Actions are influenced by the extent to which individuals feel a personal importance or intrinsic interest in doing the task and the extent to which they believe that the wanted result will follow if they try
Maslow's Need Theory (Maslow 1954)	Behavior is driven by the desire to satisfy eight hierarchically structured needs (physiological, safety, belongingness and love, esteem, cognitive, aesthetic, self-actualization, transcendence)
Alderfer's Need Theory (Alderfer 1969)	Satisfaction of the three basic needs for existence, relatedness, and growth; less strict on hierarchy
Self-Determination Theory (SDT; Deci and Ryan 1985)	Motivation continuum from motivation over extrinsic to intrinsic motivation. Four types of extrinsic motivation (external, introjected, identified, integrated). Three basic needs for autonomy, competence, and relatedness. Relatedness and competence needs lead to internalized regulation but the extent to which autonomy is satisfied determines whether introjected or identified/integrated regulation occurs
Goal Setting Theory (Locke and Latham 1990)	Individuals' representations of goals are the effective cause of behavior. Goals should be specific, difficult, and highly valued

strictly ordered in such a way that the next need automatically emerges as soon as some lower need has been satisfied. Rather, in our society people are "partially satisfied in all their basic needs and partially unsatisfied in all their basic needs at the same time" (Maslow 1954, p. 54). Maslow's needs theory has gained wide acceptance for explaining motivation in management and organizational contexts. It has also been applied in a number of other settings, for instance as a basis for defining elegance in system architecture (Salado and Nilchiani 2013). However, there has been little evidence to support it. Studies either showed no support for the proposed needs, did not represent them as independent from each other, or clustered them differently (Wahba and Bridwell 1976). Furthermore, researchers proposed adjustments to only incorporate two or three needs (Mathes and Edwards 1978).

This was accomplished by Alderfer (1969), who further developed Maslow's theory into the ERG theory by condensing it into three basic needs. *Existence* combines physiological and safety needs in a factor of lower-order needs. *Relatedness* is concerned with interpersonal relationships and the desire of status, similar to Maslow's need for belonging. The third basic need is the need for *growth*, which is comparable to Maslow's need for self-actualization. Alderfer did not propose a strictly hierarchical order but posited that unmet higher-order needs can cause more strongly desired lower-order needs. In an empirical test at a bank with 110 employees on different job levels, Alderfer directly compared his ERG theory to Maslow's theory. ERG theory resulted in more accurate descriptions of employees' needs and desires.

3.1.3 Self-Determination Theory

Self-Determination Theory (SDT; Deci and Ryan 1985) proposes a distinction between autonomous and controlled motivation. The former is referred to as *intrinsic* motivation, which is concerned with performing a task because the act of doing it is rewarding in itself. In contrast, controlled motivation is referred to as *extrinsic* motivation, which only leads to the performance of a task because external forces such as reward or punishment are present.

SDT introduces two subtheories: organismic integration theory and cognitive evaluation theory. Organismic integration theory differentiates between four kinds of extrinsic motivation along an autonomy continuum. This continuum starts with a motivation, which refers to a total lack of determination. It is followed by the four kinds of extrinsic motivation: external, introjected, identified, and integrated. *External regulation* occurs when the execution of a task fully depends on external forces. *Introjected* regulation means that a task is carried out to avoid fear and shame but the task goal is not internalized. *Identified* regulation describes a state in which a task is executed not because it is interesting but because its goals are perceived as personally useful. Finally, *integrated* regulation occurs if the value of the task at hand is deeply integrated into one's own values. However, in contrast to intrinsic motivation the behavior is still externally regulated and not resulting from the experience of doing the task itself. The continuum then ends with intrinsic motivation as the most autonomously regulated kind of motivation. SDT further employs the concept of internalization of a behaviour. Internalization is concerned with the transformation of an externally regulated behavior into an internally regulated one. In consequence, performing the respective behavior no longer requires the presence of an external force. The theory regards the concept of internalization as an overarching term for introjection, identification, and integration. These different levels describe the extent to which internalization of external regulation has taken place.

Cognitive evaluation theory, the second subtheory of SDT, incorporates the presence and satisfaction of needs as main drivers of intrinsic motivation. They are defined as "universal necessities, as the nutriments that are essential for optimal human development and integrity" (Gagné and Deci 2005, p. 337). The three needs posited in the theory are autonomy, competence, and relatedness. *Autonomy* refers to the degree to which individuals feel that they are in control of their action choices. *Competence* results from a feeling of being able to successfully execute or complete a task or action. *Relatedness* is concerned with a feeling of connectedness with other individuals, as people generally include others in the planning and execution of their actions. The needs can either be a desired result or a motive that drives behavior. The theory is mainly concerned with the consequences of need fulfillment (Gagné and Deci 2005). Satisfaction of the competence and relatedness needs is assumed to foster internalized regulation, while the extent to which the autonomy need is satisfied will determine whether introjected or identified/integrated regulation occurs. Furthermore, organismic integration theory is directly connected to cognitive evaluation theory as it highlights the needs for autonomy and relatedness to be crucial for internalization of behaviors. An individual's actions will be more autonomous the more internalized the extrinsic motivation is. Additionally, the internalization of values and belief systems is directly tied to the need for feeling a connectedness with other people.

The hypothetical relations of SDT have been tested in several studies within organizations and in other contexts. Deci (1971) demonstrated that receiving monetary rewards for intrinsically motivating tasks reduces intrinsic motivation even below a control group that received no rewards at all. The concept of internalization was further supported by Deci et al. (1994), who found that it was facilitated by the three contextual factors conveying choice, acknowledging the individual's feelings, and providing a meaningful reason. This latter factor of a personally meaningful reason can support the individual in comprehending why the self-regulation of an action might be of personal use. Zhang et al. (2016) investigated how the different kinds of motivation on the autonomy continuum relate to employees' performance. Only identified regulation strongly predicted performance, because identification with the goals and values of an organization keeps employees more focused on the long-term importance of their current job. This focus may promote persistence in performing less compelling but significant work activities. Additionally, a manager's autonomy support was related to positive work outcomes (Deci et al. 1989) and greater need satisfaction (Baard et al. 2004). Concerning the organization of work, Nesbit (2016) assessed the correlation between employees' perception of different knowledge management designs and their work motivation. Using correlation and cluster analysis, Nesbit found that the use of a

well-adjusted knowledge management system (i.e., a system with a design that matches the employee's work motivation) induced more autonomously controlled motivation, thereby supporting SDT. Moreover, the concept of need satisfaction has been applied in system design. For instance, it was used to design of software learning system for children, which lead to an increase in engagement and motivation in using the system (Ford et al. 2012). It has also been helpful in designing an app used to promote physical activity (Haque et al. 2016).

Taken together, SDT provides a valuable framework that has been applied and evaluated in various settings. Its theoretical structure of an autonomy continuum and three clearly defined needs makes it possible to adapt it to new contexts and environments.

3.1.4 Goal Setting Theory

Locke and Latham's Goal Setting Theory (1990) focuses on goals rather than tasks and stresses the importance of goals and their attributes in driving actions. It integrates earlier goal theories with Bandura's Social Cognitive Theory (1986). According to the Goal Setting Theory, goals direct attention and effort in such a way that higher goals lead to greater effort. Goals also affect people's determination to reach them if the time expended can be chosen freely. Moreover, goals affect actions indirectly by enabling people to find and use task-relevant knowledge (Locke and Latham 2002). The theory assumes that certain attributes of goals will maximize performance: Goals need to be specific, difficult and highly valued. At the same time, people need to understand which actions are necessary for goal completion, and they need to feel competent to carry out these actions (Gagné and Deci 2005). The role of goal setting and its influence on employee performance has since been empirically validated (Asmus et al. 2015; Teo and Low 2016). It has also been theoretically connected with the concepts of information system design (Esposito and Virili 2014) and gamification (Fortes Tondello et al. 2018).

3.1.5 Summary and integration

When comparing the general motivation theories presented above, a number of common constructs become apparent. Maslow and Alderfer both define the satisfaction of fundamental needs as the main driver of action. While SDT also adopts this notion, it does not assume a hierarchy or order of needs but differentiates between internally and externally motivated behavior. The former is mainly driven by the satisfaction of three basic needs (i.e., autonomy, competence, and relatedness), and the latter is represented by a continuum of internalization (i.e., transforming an externally regulated behavior into an internally regulated one). To some extent,

the concept of internalization is also present in Goal Setting Theory, according to which performance can be maximized when applying highly valued goals (i.e., goals that are more relevant to an individual's internal values and belief systems). This closeness to personal values can be found in Expectancy-Value Theory as well, which posits that an intrinsic interest in performing a task is a major driver of action.

Taken together, the main themes of the general motivation theories are the presence and satisfaction of innate needs, the importance of intrinsically motivated action, and the quality of the goals an individual pursues.

3.2 Motivation in education

Theories on how to generate and promote learning motivation are either concerned with the way the learning content is presented or with learners' subjective evaluations of their own abilities. Figure 3 provides an overview of these theories by visualizing their components and relations, and Table 2 summarizes their key concepts.

3.2.1 ARCS Model of Instructional Design

The ARCS model (Keller 1987) provides a theoretically grounded set of strategies to improve instructional material in such a way that it elicits motivation and behavior in line with the learning objectives. The model originated from earlier forms of Expectancy-Value Theory (Eccles et al. 1983; Wigfield and Eccles 2000), extending the previous two categories to four (Keller 1979, 1983): Value was divided into *attention* and *relevance*, expectancy was renamed *confidence*, and a new factor *satisfaction* was added. Attention is concerned with getting and sustaining learners' awareness and directing it to the appropriate stimuli, while relevance is concerned with eliciting interest in a topic. Confidence deals with learners' beliefs that their actions will lead to the desired results. Lastly, satisfaction indicates that personal accomplishments should be used to make learners feel good about themselves. Moreover, Keller (2010) provided a ten-step guideline on how to apply the ARCS model in a motivational design process. The steps were developed for a classroom course but can be adapted to different environments. Thus, the ARCS model is not so much a conceptual theory of motivation as it is a collection of practical strategies that builds upon earlier theoretical work.

The theoretical validity of the model and its strategies have since been tested in a variety of settings (Keller 1984, 1999; Keller and Suzuki 1988). For instance, Shellnut et al. (1999) applied the model to the design of a computer-based engineering course. They incorporated reality-based simulations, worked with industry partners to find relevant audiovisual material, and implemented self-checks to increase
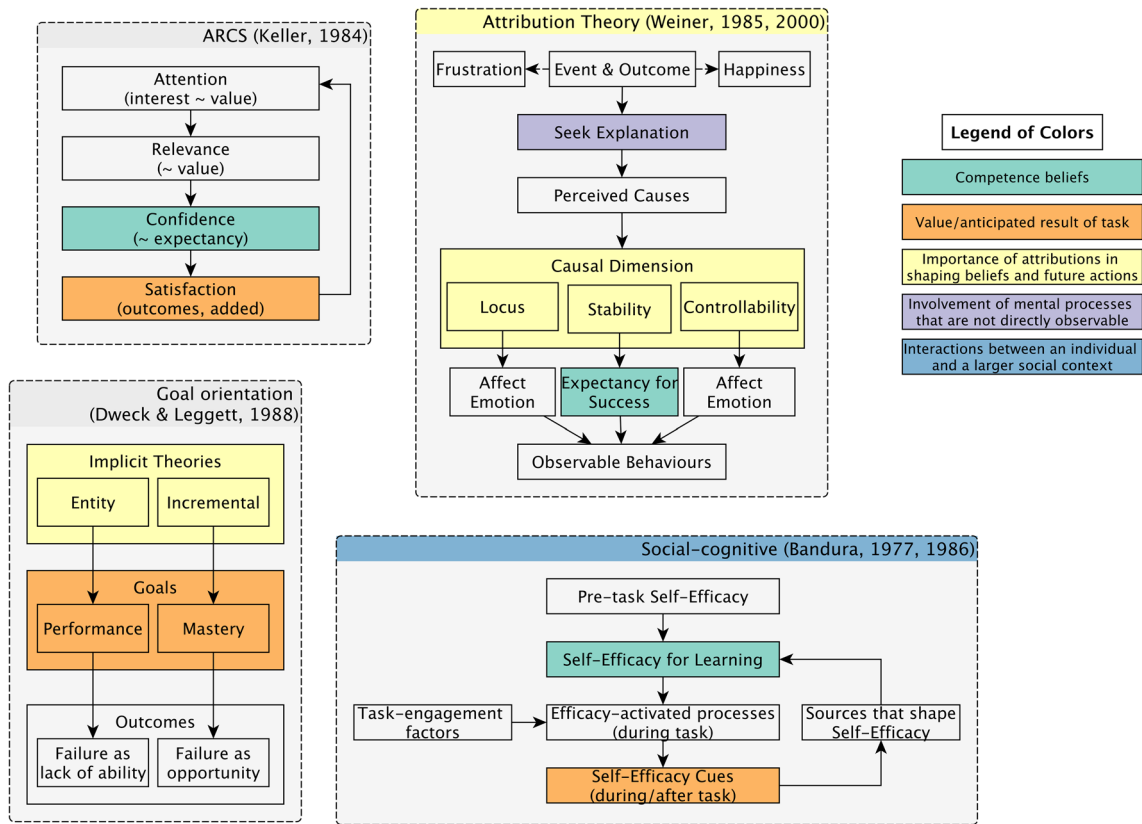
Fig. 3 Overview of motivation theories in education. Where available, adaptations of the original model structures were used, otherwise a new model representation was created in such a way that all models fit on the page

Table 2 Overview of motivation theories in education

Theory and authors	Concepts
ARCS Model of Instructional Design (Keller 1987)	Practical strategies that elicit attention, relevance, competence, and satisfaction in learners
Attribution Theory (Weiner 1985, 2000)	Future actions are determined by how past unexpected events are causally explained using the dimensions locus, stability, and controllability
Goal Orientation Theory (Dweck and Leggett 1988)	The two mindsets of fixed or changeable cognitive abilities influence motivation and goals (performance- vs. mastery-oriented)
Social Cognitive Theory (Bandura 1977, 1986)	Subjective belief about one's competence (self-efficacy) determines actions. Learning also occurs by observing models

confidence. Adaptations of the ARCS strategies also exist for computer-based and online instruction (Keller 1999; Keller and Suzuki 1988), which take into account additional constraints of distance-based learning (e.g., time, distraction, and familiarity with the learning tool). In a review of 27 studies applying the ARCS model, Li and Keller (2018) found the model to have been supportive of motivation in almost all instances.

3.2.2 Attribution Theory

One strategy of the ARCS model for promoting confidence is to "attribute student success to effort rather than luck or ease of task" (Keller 1987, p. 5). This directly builds upon Weiner's Attributional Theory of Achievement Motivation and Emotion (Weiner 1985, 2000), which proposes that learners will seek causal explanations for negative or unexpected results. Summarizing dominant ascriptions from ten empirical studies, Weiner extracted the three main causal attributions *locus* (internal or external), *stability* (fixed or variable), and *controllability* (can be controlled by the learner or not). If learners believe that a failed test was due to an error in the task description and thus had an external locus, this event will be a less motivating force than if they believe the failure was due to their own negligence in reading the task description. Less motivation will also ensue if

learners believe that the task exceeded their stable mental capabilities than if they believe that more effort would have changed the outcome. Lastly, motivation for future learning actions will be higher if learners believe that they can control the circumstances such as the learning strategy used or the effort expended. In line with the ARCS strategy, learners should be guided in attributing an unexpected success to an internal locus which they are able to control.

Attribution theory has been empirically validated in a number of studies. For instance, when investigating the causal attributions of 406 seventh-grade students after succeeding or failing in a math exam, significant relations were found between achieved scores and effort attributions following success or failure (Woudzia 1991). Thus, attributions play a central role in guiding future behavior based on perceived causes of past events. Children already attribute successes and failures differently and these attributions can be guided by explicitly framing events in a certain way, for instance by attributing successes to internal loci.

3.2.3 Goal Orientation Theory

Merging earlier goal theories with the stability and controllability attributions of Attribution Theory, Dweck and Leggett (1988) developed their Goal Orientation Theory. It is concerned with implicit unconscious attributions regarding one's own ability to learn and differentiates between an entity mindset and an incremental one. An entity mindset entails the unconscious self-theory that intelligence and skills are fixed and cannot be changed, whereas an incremental mindset assumes them to be changeable by learning and effort. The two mindsets are the basis for either performance or mastery goals. Learners with performance goals want to be presented in a good light and avoid being perceived negatively. In contrast, learners with mastery goals strive to gain knowledge and conquer new challenges. In case of failure, performance goals lead to attributions of lacking skill, and in consequence new challenges are avoided as they pose a risk. Conversely, mastery goals lead to seeing failure as a possibility to learn and grow, with challenges acting as a driving force for increased effort.

In a series of studies, it was assessed whether school children were either performance- or mastery-oriented (Diener and Dweck 1978, 1980). The children were then asked to complete a set of tasks, with the last four tasks being somewhat too hard for children their age. The children's thoughts and feelings, their hypothesis-testing strategies, and their predictions of future performance were monitored. During the harder tasks, children without mastery-orientation showed more negative affect and self-cognition as well as pronounced performance losses. These "helpless children viewed their difficulties as failures, as indicative of low ability, and as insurmountable" (Dweck

and Leggett 1988, p. 258), whereas the mastery-oriented children viewed their difficulties not as failures but as challenges which could be conquered by effort. In terms of actual performance, mastery-oriented children reached the learning criterion in the difficult tasks almost as often as in the easier tasks. These findings support the assumption of Goal Orientation Theory that different goal and effort orientations depend on the mindset of the learner.

3.2.4 Social Cognitive Theory

In his Social Cognitive Theory, Bandura offered a new perspective on learning by focusing not only on the cognitive aspect but also on social factors (Bandura 1977, 1986). The theory posits that human learning happens through observation of behavior and interaction with the environment. The cognitive aspect of the theory relies on individuals' ability to reflect their actions and use this reflection as the basis for motivated action. The social aspect sees individuals as active learners who consciously engage with their environment. The concept of observational learning proposes that individuals reproduce behaviors and actions they observe someone else conduct successfully, and avoid behaviors when the observed person fails in executing them. Therefore, behavior is determined by a triadic reciprocal causation where personal determinants, a person's environment, and the behavior dynamically interact with each other. The cognitive aspect relies on individuals' ability to reflect their actions and use this reflection as the basis for motivated action. The core of the theory is the concept of self-efficacy: the personal belief that a given situation can be mastered. However, if self-efficacy is low, a situation may not be mastered even if the necessary physical or mental abilities are present. This distinguishes self-efficacy from a simple judgement of one's own abilities.

In the context of education, relations between self-efficacy beliefs and learning results have been reported (Multon et al. 1991). There also is meta-analytical evidence for a correlation between learning results and self-efficacy beliefs of college students, even after controlling for socio-economic status (Robbins et al. 2004). Furthermore, Middleton et al. (2019) highlighted the practical value of Social Cognitive Theory in a study on information-literacy with a special focus on information-seeking behavior and knowledge sharing.

3.2.5 Summary and integration

When comparing the central elements of theories on motivation in education as well as the general motivation theories, several similarities become apparent. First, *task value*, one of the central elements of Expectancy-Value Theory, also recurs in Attribution Theory, with the difference of being mediated

by emotions in the latter and therefore not impacting behavior directly. Tasks are also evaluated in Goal Orientation Theory, where they either drive performance- or mastery-oriented behavior. Therefore, the presence of some kind of task which is assigned a subjective value is a common pattern across theories. Second, the *expectancy of success* is a central element not just in Expectancy-Value Theory and the related ARCS model but the attributional dimension stability in Attribution Theory also directly affects this factor. The concept of self-efficacy from Social-Cognitive Theory is comparable to success expectancy as well, although it is more specific in terms of the goals, the context, and the task at hand. A third common pattern across theories is the presence of *attributions* and their role in affecting future action choices. Attributions can be compared to some of the motivational beliefs of Expectancy-Value Theory and the implicit theories of Goal Orientation Theory. However, the latter assumes that subjective controllability varies between learners, while Attribution Theory considers controllability attributions to be fixed to an event. Finally, the importance of *social relationships* and an individual's interaction with the environment is mainly posited in Social Cognitive Theory, but such interactions are more or less apparent in other theories as well. For instance, Expectancy-Value Theory argues them to be the main initializers of cognitive processes. Moreover, they are comparable to the need for belongingness and love in Maslow's Needs Theory and to the need for relatedness in SDT.

Taken together, main elements of the presented theories on motivation in education are the value of a task or its anticipated reward versus punishment, beliefs in one's own abilities, the presence of attributions and their role in shaping future behavior, and the presence of a larger social context in which an individual's actions are embedded.

3.3 Motivation at the workplace

Motivation theories from the area of education do not convey all the factors that need to be thought of when implementing assistance systems at the workplace. This is because workplaces provide an environment with particular constraints that all possible actions derived from a theory must adhere to. Figure 4 provides a visual overview of theories on motivation in the context of work and the relations of their individual factors, and Table 3 summarizes their key concepts.

3.3.1 Needs theories concerning the workplace

Just like the theories by Maslow (1954) and Alderfer (1969), Herzberg's Two-Factor Theory (1966) tries to classify motivational drivers. It proposes the existence of two different categories of factors which are not ordered hierarchically. On the one hand, *hygiene factors* are those that do not lead to satisfaction and often go unnoticed if they are present, while their absence causes feelings of dissatisfaction. Examples include pay and job security. On the other hand, *motivators* can lead to satisfaction if they are present, but their
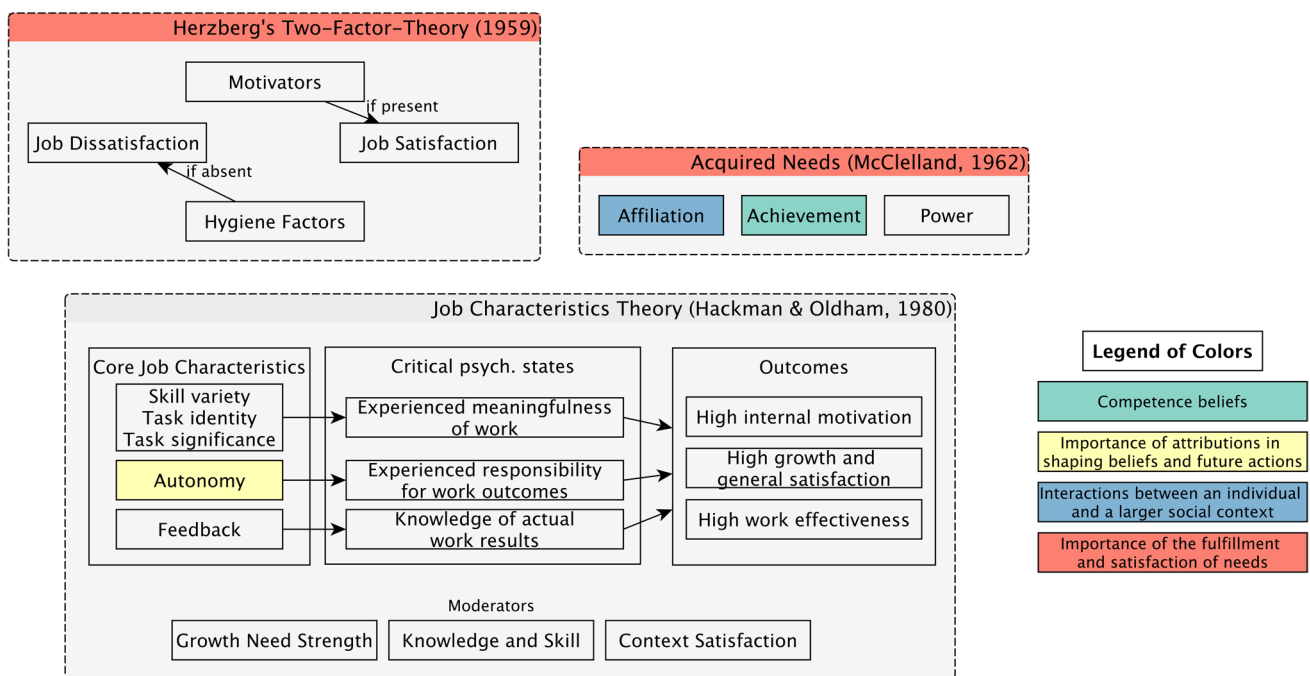

Fig. 4 Overview of motivation theories at the workplace. Where available, adaptations of the original model structures were used, otherwise a new model representation was created in such a way that all models fit on the page

Table 3 Overview of motivation theories at the workplace

Theory and authors	Concepts
Herzberg's Two Factor Theory (Herzberg 1966)	Two complementary motivational drivers: hygiene factors cannot be absent (pay, job security) and motivators have to be present (responsibility, success) to increase motivation
Need Achievement Theory (McClelland 1962)	Three learned needs for affiliation, achievement, and power that employees strive to fulfill, focus on strength, not satisfaction
Job Characteristics Model (JCM; Hackman and Oldham 1980)	Focuses on the design of task, autonomy, and feedback and incorporates personal goals, skills, and the need to grow as moderators. Job Diagnostic Survey (JDS) as a tool that measures all factors except the moderators knowledge, skill, and context satisfaction

absence does not necessarily hinder it. Examples are challenges, responsibility, and recognition, which are mainly concerned with personal growth. A combination of hygiene factors and motivators will, therefore, lead to favorable outcomes regarding satisfaction, motivation, and success. Hinton (1968) investigated the reliability of the theory by repeatedly asking participants to rank different factors. No consistent ratings were found. Additionally, the proposed unidimensionality of factors seems to be unwarranted: A study by Kobayashi and Igarashi (1981) showed that motivators can also lead to dissatisfaction, in contrast with Herzberg's original theory.

An additional needs-related theory has been directly developed for the workplace: McClelland's Need Satisfaction Theory (1962). It proposes the existence of three needs which have been learned throughout an individual's life: achievement, affiliation, and power. *Affiliation* is concerned with feelings of belonging to a group and taking part in cooperative tasks. *Achievement* encompasses the accomplishment of set goals via one's own performance. *Power* describes the desire to influence others. As these needs are believed to differ between individuals, they can also compete within an individual. For instance, a person with a high need for power might be less inclined to fulfill the need for affiliation, and will actively seek out opportunities to influence others (e.g., leadership positions). In a review of five studies that investigated the relationship between the motivation of managers and the effectiveness of their organization, Andersen (Andersen 1999) found the need for power to be significantly related to organizational effectiveness. Furthermore, McClelland's theoretical claims could be confirmed with 565 managers (Andersen 2018): Both the existence of motivation profiles was supported as well as their variance between managers and organization types.

Taken together, needs theories emphasize that the motives driving human behavior can be condensed into a number of basic needs. However, it is not completely clear what these needs are and how they are organized. Additionally, some theories lack empirical support for their assumptions.

3.3.2 Job Characteristics Model

While the theories discussed so far are mainly concerned with the factors determining and influencing motivation, Hackman and Oldham's Job Characteristics Model (JCM; Hackman and Oldham 1980) focuses on the actual task at hand. The model proposes that the most effective way of instilling work motivation is the design of the work itself. The authors establish three blocks of core characteristics of work tasks: *autonomy*, meaning the extent to which employees can independently and freely choose their procedures, *feedback*, which represents the extent to which employees receive clear, detailed and specific feedback about their work effectiveness, and *task factors*, which are concerned with the variety and significance of a task as well as the identification with that task. These three blocks influence three critical psychological states, respectively: Autonomy increases the felt responsibility for the work outcomes, feedback affects the knowledge of actual work results, and well-designed tasks lead to a higher experienced meaningfulness of work. These states, in turn, lead to outcomes such as high internal motivation, high growth and general satisfaction as well as high work effectiveness. The influences between the core characteristics and critical states as well as between the critical states and outcomes are moderated by employees' knowledge and skill, their growth need, and context variables such as satisfaction with co-workers and superiors, pay, or job security.

To test their model, Hackman and Oldham developed the Job Diagnostic Survey (JDS; Hackman and Oldham 1975), which measures all factors of the model except the moderators knowledge, skill, and context satisfaction. It can be used to assess job designs to find room for improvement. This is accomplished by measuring the current motivation and satisfaction of employees, the potential of existing jobs to motivate, and employees' inclination to change. In a meta-analysis of nearly 200 studies on the JCM, the proposed correlations were found to be reasonably valid, and the mediating role of the critical psychological states between

core characteristics and outcomes was empirically supported (Fried and Ferris 1987). More recent research used the JCM as a predictor of work motivation in bank managers (Hadi and Adil 2010) and assessed its role in predicting job performance of public servants (Johari and Yahya 2016) and service-oriented organizations (Pei et al. 2018). This work further supports the contribution of JCM to job design and motivation research. Therefore, JCM together with JDS provides valuable tools not only for designing new tasks but also for assessing employees' current motivation and satisfaction to improve existing tasks.

3.3.3 Summary and integration

The theories presented above combine elements from work and educational motivation theories as well as from general motivation theories. Goal Setting Theory directly builds on Bandura's concept of self-efficacy and earlier goal theories. Furthermore, a meaningful reason for a given goal may foster integrated regulation as envisioned in SDT (Deci and Ryan 1985). A similar concept has been suggested by Expectancy-Value Theory, which defines a task as needing some personal importance to be relevant and motivating, as well as by Locke and Latham who stated that a meaningful reason can enhance goal acceptance (Gagné and Deci 2005). However, their Goal Setting Theory does not discriminate between different kinds of motivation, whereas SDT proposes a difference between extrinsic and intrinsic motivation.

SDT also integrates the notion of earlier needs theories that action results from the drive to satisfy certain innate needs. However, Gagné and Deci (2005) criticize that needs theories (Alderfer 1969; Herzberg 1966; Maslow 1954) only concentrate on what invigorates a certain behavior but do not specify the processes directing behavior. The needs defined in SDT can further be differentiated from other needs theories (e.g., McClelland 1962) as they are believed to be innate and therefore mainly focus on need satisfaction instead of on inter-individual differences in need strength. Additionally, due to the fact that SDT was developed empirically, it provides a scaffold for potential research questions, making it more empirically testable than the other needs theories.

While it can be argued that the outcome of high internal work motivation in Hackman and Oldham's JCM bears much similarity to the SDT concept of autonomous motivation, JCM does not distinguish between different kinds of motivation as proposed by Deci and Ryan (1985). Therefore, JCM cannot examine the negative consequences of introjected regulation (Gagné and Deci 2005). Three other differences between JCM and SDT should be noted: First, while the JCM core characteristics (i.e., autonomy, feedback, and task factors) are comparable to the autonomy and competence needs in SDT, the latter theory also introduces

relatedness as a third need. Second, SDT does not focus on interpersonal differences in need strength as it assumes that every individual strives to satisfy all three fundamental needs. Third, JCM does not differentiate between internal and external motivation, which are the main components of SDT.

Taken together, motivation theories in the context of work have mostly focused on people's needs. Later, this drive to satisfy one's needs has been incorporated into a task-focused approach, either as a general guidance of task design which has mainly been applied in vocational settings (SDT) or as a dedicated job design theory (JCM). The needs and design elements proposed in these theories should be considered when applying motivational education theories and strategies in the workplace.

3.4 Motivation in system design

If motivating concepts from the area of education are to be applied in a work context, it must be considered which constraints may help or hinder learning motivation. As most tasks in industrial environments are executed by interacting with technological devices, the design of these devices and its impact on motivation should be investigated. Therefore, the following sections present motivation theories in technology and system design. Figure 5 visualizes the individual components and relations of these theories, and Table 4 provides an overview of their key concepts.

3.4.1 Motivational affordances

In his Ecological Approach to Visual Perception, Gibson introduced the term affordance as something that "implies the complementarity of the animal and the environment" (Gibson 1979, p. 127). For instance, if a surface is flat, horizontal, and knee-high relative to the person perceiving it, it should look sit-on-able and thus create an affordance of sitting. Norman extended Gibson's view on affordances and transferred it to the context of design (Norman 1988, 2013). According to his definition, a certain affordance only exists if it is supported by both the properties of an object and the capabilities of a person.

Building upon Norman's definition, Zhang (2008a) introduced motivational affordances as an important component of information and communication technology. Motivational affordances comprise the "properties of an object that determine whether and how it can support one's motivational needs" (Zhang 2008a, p. 145). These needs largely overlap with the ones proposed in SDT, with the addition of affect and emotion as a motivational need. For each need, Zhang presented a set of concrete strategies and design principles. They incorporate motivational affordances such as
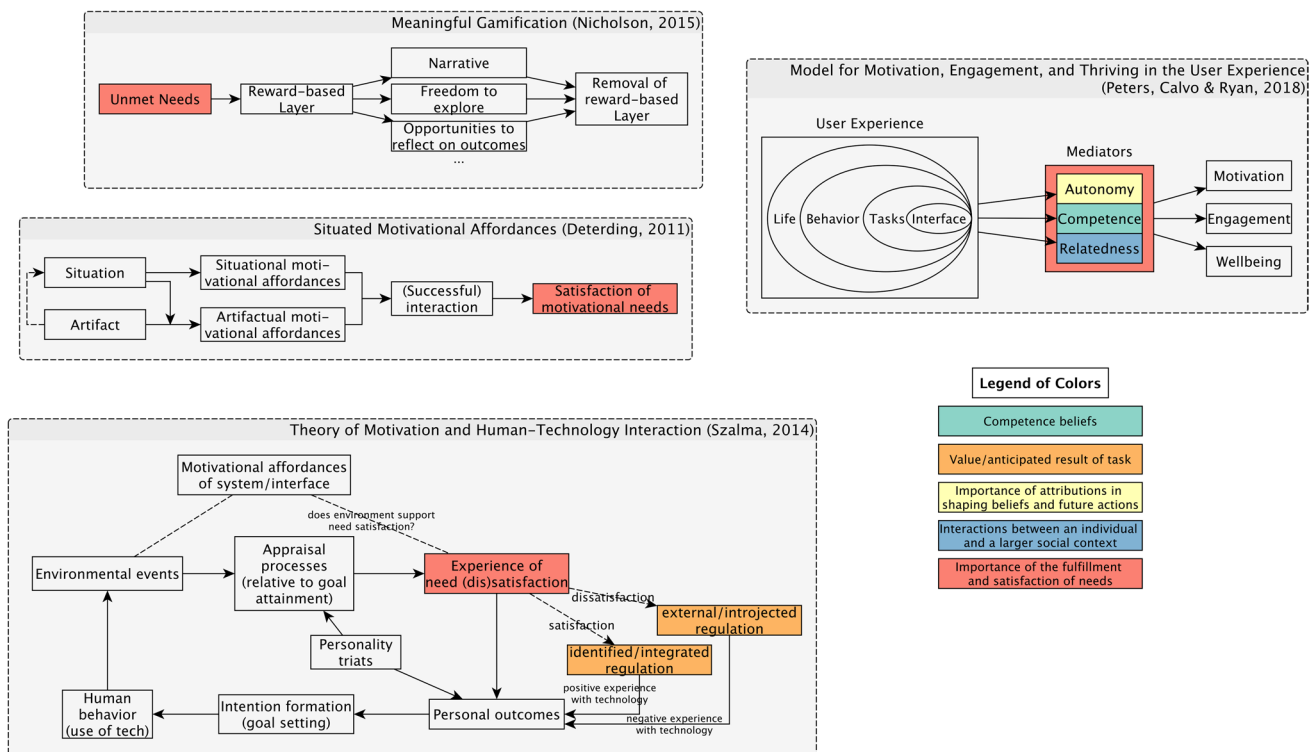
Fig. 5 Overview of motivation theories in design. Where available, adaptations of the original model structures were used, otherwise a new model representation was created in such a way that all models fit on the page

Table 4 Overview of motivation theories in system design

Theory and authors	Concepts
Motivational Affordances (Zhang 2008a; Deterding 2011)	Relationship between the properties of an object and the motivational needs of the person
(Meaningful) Gamification (Nicholson 2015)	Transference of design elements found in games into non-game contexts in or to harness their motivational effects. Meaningful if designed as a journey and new experiences are connected with previous beliefs
Theory of Motivation and Human–Technology Interaction (Szalma 2014)	Motivation, higher performance, and a positive experience ensue if environmental structures support need satisfaction
Model for Motivation, Engagement, and Thriving in the User Experience (METUX; Peters et al. 2018)	Six spheres of user experience that influence motivation via the satisfaction of the three basic needs for autonomy, competence, and relatedness. The spheres are adoption, interface, task, behavior, life, and society

customization for autonomy, challenge levels and feedback for competence, blogs or group-based games for relatedness, and games or attractive design for emotional needs.

Zhang's motivational affordances only describe the properties of objects. Therefore, Deterding (2011) added the context or situation as an important factor. He defined situated motivational affordances as affordances that "describe the opportunities to satisfy motivational needs provided by the relation between the features of an artifact and the abilities of a subject in a given situation, comprising of the situation itself (situational affordances) and the artifact in its situation-specific meaning and use (artifactual affordances)" (Deterding 2011, p. 3). For instance, a "Start" button in a car that is turned off and standing still is more motivationally salient than the same button in a car that is moving. The standing car in combination with the driver's wish to move it represents the situational affordance, and the button represents the artifactual affordance in this specific situation. To be acted upon, these affordances must be perceived. Therefore, a single artifact may impact motivation differently for the same person in a different situation or for different people in the same situation.

In their Design For Assembly Meaning framework, Parmentier et al. (2019) build upon Gaver's (1991) four types of affordances: First, false affordances appear as if they could be acted upon, even though this is not possible. Second, correct rejections do not convey the possibility for action and cannot be acted upon. Third, perceptible affordances can be acted upon and are visible. Fourth, hidden affordances can be acted upon but are not perceived. Parmentier et al. propose possible pathways by which affordances themselves or their perception can be altered. Designers should shift the dynamics between the four types of affordances towards perceptible affordances for desired affordances, and towards correct rejections for undesired affordances. This can be achieved by altering the perception of affordances (via perceptual cues such as product semantics) and by altering the presence of affordances themselves (by adding or removing physical constraints).

Since the introduction of theories focusing on motivational affordances, motivational affordances in general and certain affordances, in particular, have been found to correlate with different learning types (Engedal 2015) and personality types (Karanam et al. 2014): Some people react differently to the same affordances. This stresses the importance of gaining information about potential users before a system is implemented. Furthermore, many motivational affordances employ elements that are closely related to the concept of gamification.

3.4.2 Gamification

The development of Deterding's situated motivational affordances was mainly motivated by two shortcomings of gamification applications: a lack of granularity concerning the design focus and too little emphasis on social aspects. The term gamification is concerned with the transfer of game design elements in contexts other than games (Deterding 2011). This transfer "attempts to harness the motivational power of games to promote participation, persistence and achievements" (Richter et al. 2015, p. 23). In a way, gamification research takes a comparable place to the ARCS Model of Instructional Design in that it mainly provides a set of strategies to motivate a certain behavior. The main difference is that gamification is a comparably new concept that has yet to be examined and implemented to the same extent as the ARCS model. Nevertheless, the concept has already been applied in a number of settings. In their overview of gamification, Richter et al. (2015) provide examples for successful applications in politics and health (Lee and Hammer 2011), education (Raban and Greifman 2009; Ravid and Rafaeli 2000) and the workplace (Reeves and Read 2009).

Nicholson (2015) argued that there is a difference between what he considers *BLAP* gamification and meaningful gamification. The former is concerned with adding badges, leaderboards, achievements, or points to a system, which is generally easy to implement and will show almost immediate effects. Such a reward-based implementation may be useful for teaching a new skill with a real-world value. However, it might also compromise motivation in the long run, for instance when students refuse to learn non-rewarded material. Instead, system designers should provide an environment that aids users in finding their own reasons for performing a certain behavior. Nicholson suggested using the cognitive evaluation subtheory of SDT, with need satisfaction as a central point behind the implementation of gamification elements. He defined the term meaningful gamification as "using game design elements to help build intrinsic motivation and, therefore, meaning in non-game settings" (Nicholson 2015, p. 4). The notion of meaning in this context is based on Mezirow's model of transformative learning (1991), which argues that long-term change requires connecting new experience with previous beliefs. Therefore, Nicholson also integrated the organismic integration subtheory of SDT, because internalized rather than extrinsic motivation will ensue if personally meaningful connections are created. Nicholson (2015) put forward a global strategy of how meaningful gamification may be implemented. The gamification system should be designed as a journey which provides a known end to the user. Designers should start with examining unmet needs before a reward-based layer is implemented to get users to start using the system. This reward-based layer then should be replaced by elements that are more meaningful with regard to the overall goal. Meaningful elements could be narratives, freedom to explore, or opportunities to reflect on past outcomes. Finally, the gamification layers should be removed entirely to make room for an application in real-world surroundings.

A possible issue arising with this novel mode of designing work activities is user acceptance. Korn et al. (2017) noted that in many industrial environments the workers' focus is less the interface itself than on the current work task. Therefore, any gamification element should be unobtrusive, especially in critical situations. Gamification input should be designed in such a way that the regular work tasks become the input of the system, therefore adhering to the concept of natural interaction using humans' five senses (Tavares et al. 2013). A second requirement is to blend out the gamification system in case of increased stress levels at the workplace.

Taken together, gamification is a relatively new concept that has been discussed in the literature as either helping or hindering motivation. The research presented in this section suggests that gamification can drive actions in the long run only if it is designed to be meaningful for the user.

3.4.3 Theory of Motivation and Human–Technology Interaction

In his Theory of Motivation and Human–Technology Interaction, Szalma (2014) applies the core concepts of SDT to the context of technology design and also integrates Zhang's concept of motivational affordances (Zhang 2008a). According to the model, a starting point is an environmental event, such as the behavior of a technology being used. This technology offers motivational structures, which are a "set of structures in the environment that offers opportunities for the experience of autonomy, competence, and relatedness" (Szalma 2014, p. 1461). This can be realized via self-regulation, effective technology use, the learning of a new skill, and a general positive relationship between individuals and their environment. These events will then be processed in terms of their need satisfaction. If the latter is experienced, it will lead to personal outcomes such as a positive experience with the technology or higher performance and well-being. These processes are influenced by personality traits. The outcomes, in turn, affect intention formation, which is the basis for the actual behavior. While there has been little empirical evaluation of the theory per se, its main concepts of motivational affordances and need satisfaction are deeply grounded in the research on gamification and SDT.

Szalma proposes five principles of eudaimonic design, which is concerned with "well-being as a high level of psychological functioning and self-realization of nonmaterial goals (in particular, goals that, when attained, satisfy the three basic needs) rather than attaining the purely hedonic goals of pleasure or pain avoidance" (p. 1462). According to the first principle, design should be *functional*, meaning it should serve a purpose relative to the overall goal and also match the user's skill level. The second principle is *eudaimonic design*, meaning the satisfaction of an individual's needs through the use of an interface with high motivational usability: Autonomy is enhanced by choice in setting goals and selecting procedures, a meaningful rationale, and accountability. Competence is supported by an intuitive interface that matches the user's skills and provides feedback. Relatedness needs can be satisfied by feelings of connectedness to others and the notion that the technology serves the person. The third principle, *self-concordant goals*, is concerned with the user's beliefs and values, which should be accounted for to maximize internal motivation. The fourth principle is *need satisfaction*, stating that the experience of interacting with the system will be enhanced if this interaction satisfies the user's needs. The fifth principle is concerned with the *organizational context*, meaning that the factors that support need satisfaction at the interface level should also be addressed at higher socio-technical and organizational levels.

The author provides guidelines for incorporating these principles into the design process. In the first step, the task, its function, and the users of the technology are analyzed. Second, characteristics of the task and the environment are identified that support and influence need satisfaction via motivational structures (see above). For instance, autonomy needs can be satisfied via a choice in setting goals and selecting procedures. Third, it is specified how these motivational structures influence performance. Fourth, a user analysis is carried out to determine the degree of goal internalization. In a fifth and final step, the actual design of the interface with need satisfaction in mind is conducted, before it is evaluated with regard to its effect on need satisfaction and well-being.

Taken together, the theory combines research on affordances and need satisfaction as outlined in SDT, and therefore profits from the research results in these areas. This makes it a promising theory, although the specific relations that it posits will have to be evaluated further.

3.4.4 Model for Motivation, Engagement, and Thriving in the User Experience

Peters et al. (2018) suggested that technology influences motivation via the need satisfaction proposed in SDT. In their model for Motivation, Engagement, and Thriving in the User Experience (METUX), they describe six spheres of user experience that can be influenced by technology design. The first sphere, *adoption*, is concerned with the point at which a technology is used for the first time. The second sphere, *interface*, describes the experience of interacting with the technology. The third sphere is concerned with the *task*, describing the experience of fulfilling a technology-specific action. The fourth sphere, *behavior*, concerns the overarching activity a technology is intended to support. The fifth sphere is called *life* and covers additional factors outside technology use, and the sixth sphere, *society*, includes additional people besides the users of the technology. These six spheres influence motivation, engagement, and well-being and are mediated by the SDT needs for autonomy, competence, and relatedness.

The authors introduced the concept of coexisting spheres with rather fluid boundaries to emphasize that needs can be fulfilled in one aspect of design but not necessarily in another. For instance, an interface may support the need for relatedness by offering the option of a chat, but the task it is used for does not entail communicating with others. For each of the spheres they adapted validated questionnaires from comparable contexts or suggested the use of readily available scales to measure the level of need satisfaction (Chen et al. 2015; Ryan and Connell 1989; Ryan et al. 2006; Williams and Deci 1996).

Taken together, METUX combines user experience with need satisfaction in a layered design. This makes it possible to individually investigate the layers, for which the authors have provided dedicated instruments. This combination opens up new ways of looking at technology and its influence on human motivation.

3.4.5 Summary and integration

The concept of affordances has long been an important factor in the design of physical and digital objects (Gibson 1979; Norman 1988). Zhang (2008a) combined it with motivation research in his motivational affordances, and Deterding (2011) introduced the situation as an important factor by proposing situated motivational affordances. The concept of motivational affordances has been directly integrated into Szalma's Theory of Motivation and Human–Technology Interaction (2014), which also integrates and builds upon the basic needs of SDT and their relation to the motivation continuum. METUX (Peters et al. 2018) does this as well but focuses more on the coexistence of different layers of user experience and technology, which can be influenced by the design interfaces and this influence is mediated by need satisfaction. Furthermore, the task sphere in METUX can be compared to tasks as defined in Expectancy-Value Theory, which assumes that action is mainly driven by an intrinsic interest in performing a task and the expectancy of success. Another angle of system design, gamification, can be seen more on the strategy side and as a means to support need satisfaction. Depending on the kind of gamification elements that are used, it will either support short- or long-term motivational outcomes. The latter can be supported using meaningful gamification.

Research on motivation in system design, therefore, focuses directly on specific elements designers can use to instill certain behaviors. On the other hand, it also emphasizes the need to investigate factors outside of the interaction with the system or technology such as the situation or, more globally, an organization or society as a whole. The following section discusses how these elements can be integrated with those presented in the two previous sections on motivation in education and the workplace.

4 Model development

The goal of the present article was to develop practical strategies that help increase the motivation of operators to learn more about their machine or system. To derive these strategies, different motivation theories from the three areas motivation in education, at the workplace, and in system design were collected. They were integrated into a final model of motivational assistance system design in industrial production (MADIP) that aims at increasing learning motivation (see Fig. 6).

At the core of the model lies the assistance system itself. It is comprised of the three spheres interface, tasks, and behavior as introduced in the METUX model (Peters et al. 2018). In an industrial context with medium to high levels of automation, the *interface* is used to monitor and control aspects of the socio-technical system, and it also has the potential to support learning. Depending on the satisfaction of the needs for *autonomy*, *competence*, and *relatedness* via perceived *motivational affordances* in the interface, an interaction with the affordances either elicits *external or internal motivation*. For instance, an interface that offers the possibility to customize its toolbar will satisfy the need for autonomy. Conversely, this need will be compromised if actions that require multiple clicks have to be completed many times during a shift and there is no possibility to configure the layout. Due to the fact that motivational affordances have to be perceived to drive actions, they are shown with a dashed
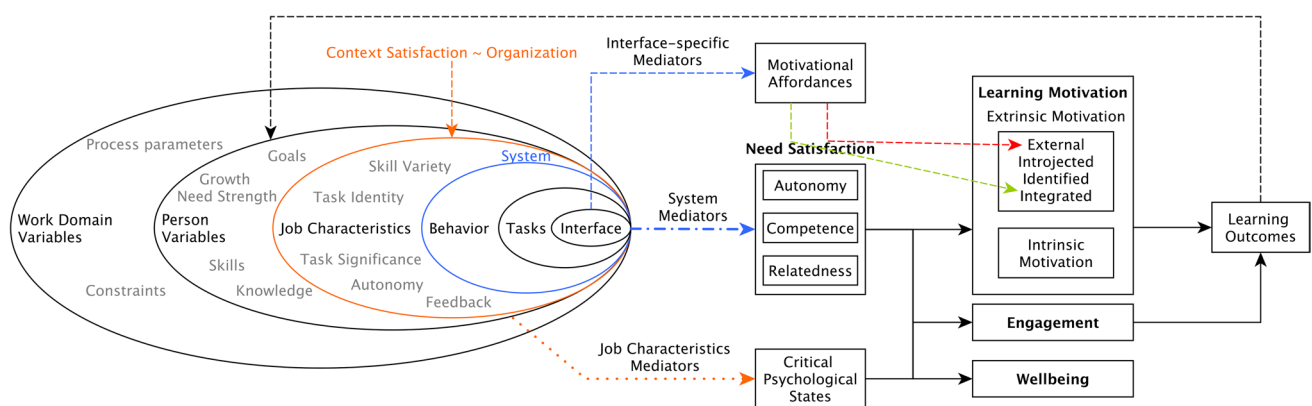

Fig. 6 Theoretical model of motivational assistance system design in industrial production. The dotted arrow relates to the JCM, the dash-dotted arrow to the system layer. Dashed arrows concern probable effects that do not necessarily have to exist (e.g., an interface might not act on need satisfaction via specific motivational affordances if they are not perceived by the user)

arrow in the model, indicating an optional relation between the interface-specific mediators and learning motivation.

As described above, interfaces are generally used to execute some kind of *task* relevant to the current situation or system state. Therefore, the interface will only provide sufficient support for need satisfaction if the artifacts presented in it are relevant in the context of the current task. For instance, a button with which a second operator can be informed about a certain system state will only satisfy the need for relatedness if the situation requires contacting this second operator. A collection of these tasks then constitutes a *behavior* such as operating a machine or producing some kind of product.

The model includes two types of mediators: interface-specific mediators and general system mediators. Interface-specific mediators (i.e., motivational affordances) mediate the effects of the interface on need satisfaction and on the outcomes—learning motivation, engagement, and well-being. As only the interface can mediate the outcomes via motivational affordances, this mediator is shown individually as a subset of the system mediators. These system mediators (i.e., satisfaction of SDT needs) in turn mediate the effects of all three system components—behavior, tasks, and interface—on the outcomes. This is similar to a concept introduced by Baxley (2003), who distinguishes between structure, behavior, and presentation. Structure represents the conceptual and organizational basis of the experience. Behavior defines the anticipation of the user's action as well as the reactions of the system. Presentation represents the interface as seen by the user. The author argues that those elements the user is less aware of (i.e., structure and behavior) have the highest impact on usability as fundamental deficiencies in them can be altered or improved less easily than the interface. Therefore, we further differentiate between these impact levels, also in terms of their mediating qualities within the model.

The system spheres, however, do not stand on their own but are dependent on *job characteristics* as outlined in the JCM (Hackman and Oldham 1980). If the task and behavior components of the system are designed with the JCM core characteristics in mind, this will impact motivation, engagement, and well-being via mediation through the critical psychological states—experienced meaningfulness of work, felt responsibility for the work outcomes, and knowledge of actual work results. Employees should, therefore, be able to decide which procedures to use in the current situation, and receive clear and detailed feedback about their performance. Additionally, the task at hand should vary in skill, offer the opportunity to identify with the action and be adequately significant with regard to the overall goals of the company. At the same time, when one of the overall goals is motivation to learn, the satisfaction of context factors such as pay and job security have to be kept in mind. The core characteristics proposed in JCM which determine the engagement

in a task and therefore the overall outcome of motivation are moderated by *person variables* such as employees' growth need strength, skills, knowledge, and goals. The outcomes of learning motivation, generally referred to as learning outcomes, also feed back into this sphere of person variables. Finally, *work domain variables* form the outermost sphere. Due to industry-specific constraints, this sphere includes the process parameters that determine the safety, complexity, and time of processes. They do not only determine which knowledge and skills an individual has to possess but also limit the freedom in designing the tasks and interfaces. In this way, work domain variables put constraints on whether and how the activities to be performed by operators can be motivating.

As can be seen in Fig. 6, the core element of the model is the system layer, following the assumption of the METUX model. Due to its flexibility in allowing different theories to co-exist, the layer structure was kept and extended with three context layers: a job characteristics layer, a person layer, and a work domain layer, allowing to adapt the model to industry-specific constraints. Generally, outer layers always act on inner layers. This is due to the fact that the model structure loosely mirrors parts of the design process guidelines outlined by Keller (1987) and Szalma (2014), which first analyze context variables such as the environment before getting more specific with a detailed user and task analysis and the design and implementation of strategies. For instance, process parameters do not only constrain a person's knowledge but also the possible feedback and variety of a task, which itself defines the interface elements to be used. The moderator variables concerning the person were directly drawn from JCM and therefore keep their relations with the job characteristics layer and the critical psychological states. The system layer acts on the person variables through mediation via need satisfaction, motivation, and learning outcomes: A motivating interface may increase employees' growth need strength or enhance their ability to execute some task.

On a meta level, the concept of gamification as well as the ARCS Model of Instructional Design act as tools to derive strategies, which are in line with the assumptions of the presented model. They also act as connectors for additional theories presented above, which have not been directly incorporated into the model to keep its complexity at a medium level while still including these concepts. For instance, the ARCS Model of Instructional Design directly builds upon Bandura's concept of self-efficacy (1977) as well as the attribution of the causes of success as defined in Weiner's Attribution Theory (1985). The strategies derived from these concepts will be discussed in the next section.

Taken together, the model fulfils two functions. First, it supports the assessment of different factors that come into play when designing assistance systems for complex work systems. Second, it explains the impact of these factors on

learning motivation, engagement, and wellbeing. It narrows down the variables that influence these outcomes by guiding designers along six spheres, starting from outer spheres and proceeding to inner spheres. These spheres increasingly focus on factors concerning the actual system and interface, therefore honing in on the system aspects closest to the operator. This also becomes apparent in the way the spheres are laid out: The context, person, and job factors start from the left and end in the system sphere, which mediates operators' need satisfaction with the interface at the rightmost point. Section 5.3 provides an example by applying the proposed model to the discrete processing industry, explaining possible ways the model assumptions can be used to increase operator motivation.

5 Deriving strategies

To introduce design elements that help motivate employees to learn more about a machine or system, different strategies can be derived from the theoretical assumptions of the model presented in the previous section. The arrangement of layers allows for a flow of design from the outside to the inside and the actual system design elements.

5.1 Context layers

The outermost layer of the model is concerned with *work domain variables*. As domain characteristics have profound impacts on operators' work (Müller and Oehm 2019), designers should first assess any specific parameters and constraints present in the industry the assistance system will be designed for. Examples are time, workplace context, and authorization. A system with the goal of enhancing learning motivation in a tightly scheduled environment will have to be designed differently than a system in a setting with less strict time constraints. Task context factors such as light, noise, or heat play an additional role in shaping the experience and visual reception of motivational features of the system. Lastly, the authorization status of an employee needs to be considered so that design implementations can focus on operations the assistance system operator is physically and organizationally able to execute. Data on these aspects can be gathered using observations or interviews as well as general research on standards, norms, and conventions of the respective industry. A suitable method to guide these activities is Work Domain Analysis (Naikar et al. 2005; Rasmussen 1986). It results in a description of the work domain on different levels of functional abstraction and decomposition, and thus provides information about what a system or machine is doing, why it is doing it, and how the specific functions are physically implemented.

The next layer is comprised of factors regarding the *person* who is carrying out the work. If people's goals, skills, and knowledge are known in addition to their growth need strength, the overall system can be designed with these individual factors in mind. Skills and knowledge are assessed regarding the industry-specific requirements from the work domain layer, while growth need strength as a moderator variable of JCM is closely related to the factors on the job characteristics layer. Furthermore, Szalma suggested a specific user analysis to determine the degree to which goals are internalized (Szalma 2009, 2014).

Concerning the *job characteristics* layer, the operator's job needs to be examined according to the core characteristics of the JCM. Any possible improvement on either task design, feedback, or operator autonomy should be investigated. A suited tool for this is the JDS (Hackman and Oldham 1975), which measures the current motivation and satisfaction of employees, the potential of existing jobs to motivate, as well as employees' inclination to change.

The layers on the work domain, person, and organization level are oftentimes not as easy to change and adapt to individuals as the inner layers on the system level. While the outer layers should be taken into account when designing motivating assistance systems, they act more as boundaries that define the outer limits and constraints of the system. They can be compared to Szalma's (2014) first step in his guidelines for incorporating motivation into technology design. They help analyze the work domain with its constraints, the users of the system, and the tasks to be carried out.

5.2 System layers

When the motivation to learn lies at the center of motivational assistance system design, a large number of practical strategies on the interface level can be derived. It is in this step of the design process that environmental structures are identified that act on the satisfaction of needs. Once it is known how these structures influence performance and motivation outcomes, the actual interface can be designed.

5.2.1 ARCS Model of Instructional Design

Keller's ARCS Model of Instructional Design (1987) can be generalized and transferred to the context of industrial production. The four factors attention, relevance, confidence, and satisfaction can be divided further into several sub-strategies. Those that can be most readily transferred will be presented in the following sections.

Attention can be evoked by introducing incongruity, for instance by presenting cases in which the application of strategies that worked in the past are no longer adequate or sufficient to solve the problem. Accordingly, operators

need to revert to knowledge-seeking behavior. An example would be confronting an operator of a packaging with a fault scenario she could previously solve by cleaning a particular sensor, but in the new situation the application of this strategy does not keep the fault from re-occurring. Learners could also play devil's advocate for their chosen strategy and then describe why this particular strategy might not work. Concrete principles could be visually represented as concreteness helps in sustaining attention. Another sub-strategy aiding in gaining and sustaining attention is variability. It can be used in interface design where different instruction formats and mediums are possible. While humorous presentations are less applicable in an industrial work environment, strategies of inquiry might be used, such as giving learners an opportunity to choose the problems they will work on. This strategy is especially useful if learners are just getting accustomed to the system because it helps them get an overview of how the system reacts to different situations. Furthermore, attention may be gained if learners can directly participate in games or simulations (Keller 1987).

To make the learning experience *relevant*, the interface should convey information about the future usefulness of the presented information. Additionally, the relevance of the experience can be increased by instructions that explicitly state which past skills and experiences the new material builds upon. In line with SDT, the ARCS model also proposes the matching of learners' needs (Deci and Ryan 1985). The need for autonomy can be addressed by providing alternatives, either in the problem choice or the selection of strategies. Moreover, opportunities to show competence under low-risk conditions should be presented. This could be done in terms of a simulation mode in which clear outcomes are defined and failure will not lead to real-world accidents. The need for relatedness can be matched using cooperative problem solving. Such cooperation can also be used in the sub-strategy of modeling (Bandura 1977), where people who already have accomplished the learning goals can be brought in as "enthusiastic guest lecturers".

If attention and personal relevance have been evoked, different strategies can be employed that aim at feelings of *confidence*. Clear learning requirements should be incorporated in terms of explicit, difficult, and yet attainable goals that are organized on an increasing level of difficulty (Locke and Latham 1990). They should be accompanied by self-evaluation tools to check one's progress. Furthermore, learners should be allowed to become increasingly more independent in their application of new skills. Self-confidence can also be increased if it is made clear that the goal is not to be perfect at every task and that failure is part of the progress (Keller 1987). This can be further extended by attributing success to effort rather than luck.

To be motivating on a long-term basis, there should be forms of *satisfaction* after the achievement of a goal. This can be done naturally via allowing learners to directly use the new skill in a real-world setting. They could also be enabled to help others who have not yet mastered this specific skill or acquired the necessary knowledge. Additionally, boring tasks should be reinforced with expected rewards, whereas intrinsic tasks may best be reinforced with unexpected, non-contingent rewards (Deci 1972). Scaffolded scheduling could be applied, where reinforcement is frequent when learning a new task and is reduced as learners get better at accomplishing the task (Belland 2014). Moreover, informative, helpful, and immediate feedback should be made available. Threats, surveillance, and external performance evaluations should be avoided whenever possible in favor of self-evaluation (Keller 1987).

5.2.2 Zhang's principles

In his Principles for Designing Motivating Information and Communication Technology, Zhang (2008b) focuses on need satisfaction. Motivating design should support autonomy by promoting personal choices, and it can be enhanced via opportunities to create and represent one's identity, for instance by personalizing parts of the interface. To design for competence needs, tasks should present an optimal challenge with timely and positive feedback. Relatedness needs can be accommodated by facilitating human–human interaction and by representing human social bonds. Zhang also introduces emotion and affect as an additional need, which should be induced via the surface or interaction features of a technology. These strategies largely overlap with those presented in the previous section and are therefore not detailed further. However, Zhang adds emotion as an important factor of motivating design, which further underlines the importance of usability and user experience in instilling motivation.

5.2.3 Meaningful gamification

Another set of strategies can be derived from the concept of gamification, where the needs of SDT can be supported using different strategies (Sailer et al. 2017; Seaborn and Fels 2015). Autonomy can be supported via configurable interfaces, control about notifications, privacy controls, and avatars. Feelings of competence can be evoked by intuitive controls, points, badges, and levels. Relatedness needs can be satisfied by creating shared goals, messaging between individuals, or the formation of groups. Due to the fact that these gamification elements might only be effective for short-term goals, Nicholson (2015) suggested incorporating them at the beginning of a journey with "layers that are peeled back and create moments of authentic engagement between the participant, the external context, and the affinity groups" (p. 19). In his RECIPE for Meaningful

Gamification, Nicholson describes the six elements play, exposition, choice, information, engagement, and reflection, which can be used to operationalize the meaningfulness of gamification elements.

The first element, *play*, encompasses the freedom to explore and fail within defined boundaries. Due to the constraints defined in the outer work domain and job characteristics layers, this is not always possible. Therefore, the possibility to explore should be provided. Nicholson compares this factor with a science museum as the "concept of a space where people can roam, explore, see where others are, engage with those others, and set temporary rules and goals" (Nicholson 2015, p. 7). In this kind of environment, badges and points are not necessary as the reward is the content itself as well as the engagement with it. *Exposition*, the second element of meaningful gamification, entails the creation of settings comparable to real-world conditions. This can be done by using simulations or by letting users create and share their own problem challenges and goals. The third element is *choice*, which is closely related to play. It is concerned with giving users the power not only to use the system but also to choose not to. On a finer level, choice can also be given with regard to the selection of problems, alternative solutions, or adjustments of interface parts. *Information*, the fourth element, revolves around letting users know more about the context of decisions, rewards, and outcomes. By letting users know why certain actions result in rewards (e.g., due to their importance in real-world settings), their need for competence is satisfied. The element of information could be implemented by immersive technologies in which users interact with mechanisms that represent real-world work domain relations. Regarding the fifth element, *engagement*, Nicholson distinguishes social engagement, which is concerned with cooperation and competition, from engagement in the gameplay experience, such as increasing difficulty and skill matching. The sixth element of meaningful gamification is *reflection*, meaning that users should actively think about their experience with the system. Reflection is comprised of a description of one's explicit actions, an analysis of these actions and how they can be transferred into the real world, as well as the application of the skills learned within the system. Taken together, the different elements of Nicholson's RECIPE for Meaningful Gamification can be integrated using simulations with constraints and variables that are specific to a particular work domain.

5.3 Example

The theoretical model for motivational assistance system design in industrial production (MADIP) lets designers derive many strategies to create an environment that increases the motivation to learn. The following section describes possible combinations of these strategies.

The outer layer of the model with its *work domain variables* focuses on analyzing the work domain the system is being designed for. In the present example, this will be the discrete processing of mass consumer goods such as cookies or spaghetti. In their comparison of the process industries and discrete processing, Müller and Oehm (2019) explained how the technical systems in these two work domains form the basis for domain-specific operator tasks, roles, and challenges. Discrete processing is mainly comprised of small to medium-scale plants with medium to high levels of automation and generally lower complexity. Most products are of low value and get processed at extremely high speeds. Faults occur frequently, but they only affect a small number of product items and most faults can be fixed quickly. They mainly have economic consequences, while safety is less of a concern. In consequence, systems are designed with cost-efficiency in mind: The processes are extremely fast, while technical safety measures such as redundancy and self-diagnosis are not common. The machines can be stopped and re-started at any time. Thus, comparably little is done to prevent faults but their consequences can easily be removed, and trial and error is possible during fault diagnosis. The human–machine interface (HMI) is mainly used to set process parameters or as a means of giving specific instructions to operators. However, most HMIs provide little information about the ongoing process or fault causes and thus do not foster learning.

After having gained an overview of the work domain and its constraints, in the second sphere *person variables* of the employees whose learning motivation is to be promoted should be considered. That is, an overview of person-specific constraints has to be created. Operator qualification in the discrete processing industry is mainly low due to a lack of dedicated job training. Oftentimes, operators only receive short introductions to the functioning of machines and then gain most of their knowledge and experience on the job. They are responsible for providing the conditions to keep the machines going, ensuring product quality, and dealing with recurring faults. Most faults are easy to detect but hard to diagnose for operators, due to the high number of possible influences combined with operators' low level of qualification. Conditions for learning are usually poor due to low job stability (Müller and Oehm 2019).

These work domain constraints and operator-specific variables should be accounted for in all subsequent design considerations. Moreover, there can be limitations of which actions operators are allowed to execute. This seamlessly leads to the subject of motivation as there might also be differences regarding the actions operators *want* to execute, depending on their self-efficacy. Therefore, an assistance system that aims at increasing motivation to learn should

first assess operator knowledge and skills. This can be done using a questionnaire that presents past or simulated problem cases and asks operators to decide which procedure would best solve the problem or what causes might be involved. The results can then be used to determine how the assistance system should interact with the operator in future dialogues. Such an initial assessment is advisable as it can compensate for an early motivation loss due to unmatched expectations on the system side, which may further lead to unsatisfied competence needs. At this step, assessing operators' individual goals and growth need strength will additionally benefit the interaction with the system.

The third sphere is *Job Characteristics*. In this sphere, operator autonomy, task design, and feedback of the job itself should be assessed, for instance using the Job Diagnostic Survey (Hackman and Oldham 1975) to investigate any possible improvement on these characteristics. Furthermore, operators' context satisfaction within the organization (e.g., job security and pay) should be examined.

After assessing the work domain constraints as well as the operator- and job-specific variables, strategies pertaining to the actual *system* can be developed. These may concern a *behavior*, a *task*, the *interface* or a combination of the three. Using the assistance system as a tool to learn should be a non-mandatory option for operators to not compromise autonomy needs. Increased voluntary usage may then be supported by the introduction of gamification elements at the beginning of the system implementation, therefore inducing and incentivizing a wanted behavior. As Nicholson (2015) notes, classic gamification elements such as points, badges and levels mainly elicit short-term results. These can be used to increase initial engagement with the system but should be replaced with more meaningful elements shortly thereafter. Results of the knowledge questionnaires can be used for an initial classification of operators into different skill levels. Reaching the next level could be coupled with collecting points after passing new problem tasks for which defined solutions exist. However, there should be a clear goal from the beginning, such as reaching a certain level or getting a certain number of points. After having achieved this goal, collecting points or reaching levels should not be a motivator for using the system anymore.

At this point, operators can be presented with a simulation mode. This mode can aid in satisfying autonomy needs when coupled with the possibility to choose from different problem tasks and to pick one's own problem-solving strategy. To increase feelings of competence, it is important that the difficulty of the simulated tasks matches operators' skill levels to make sure they are presented with conquerable challenges that are neither too difficult nor too easy. According to the ARCS Model of Instructional Design (Keller 1987), simulating real-world issues also increases the perceived relevance of the subject matter. This is the case especially when the system makes it clear which knowledge and skills the problem task builds upon, and what real-world benefits ensue from gaining the knowledge. These benefits can be further increased if actual data of the plant or machine are used to simulate the problem cases. If a simulated problem is associated with malfunctions in other machines along the process chain, the task can be expanded to be solved in a cooperative manner, which satisfies the need for relatedness. Another strategy to foster relatedness and increase learning motivation is the mentoring of novices by more experienced operators. For novices, this may also make the importance of gaining the specific knowledge easier to see, and for more experienced operators it may increase the subjective relevance of the learning subject.

In addition to a simulation mode, further strategies can be derived from the theoretical model. For instance, to realize level-dependent challenges and let operators choose from different problem simulations not solved yet, there needs to be a personal login. This allows for progress between sessions to be saved and monitored. It also enables customizing the look and feel of the interface, which has generally been shown to support autonomy needs regarding technology use (Zhang 2008a). Every design decision on a lower level should take into account possible influences and constraints from higher levels. For instance, if time is a critical factor in a work domain, individual texts and interaction modes should be short and unobtrusive. If it is clear which strategies are most suitable to achieve learning motivation as they can readily be incorporated into current structures, they should be piloted with a small subset of future users. Insights gained from this step can then be used to adapt the strategies to create a final course of implementation. The latter should then be continuously evaluated and adapted to changes in organizational structures, work domain variables, and other changes outside the scope of the model.

6 Discussion

Learning is of utmost importance in industrial production and can significantly enhance the performance of human–machine systems (Jackson and Wall 1991). However, operators often lack the motivation to learn more about their machines. The present study investigated the main drivers of motivation to learn in an industrial environment by reviewing the literature on motivation in education, the workplace, and system design. These findings were integrated into a theoretical model of motivating assistance system design in industrial production. The goal was to provide a set of practical design strategies that help increase operators' motivation to learn and prevent design elements from thwarting motivation. As most theories on motivation in industry have focused on performance outcomes, the present

study investigated ways to direct this motivation at the act of learning. It also concerned the design of assistance systems specifically, which has not yet been a focus of motivation research.

6.1 Model of motivational assistance system design

To provide a basis for future research and to derive strategies, a theoretical model of motivational assistance system design was introduced. It assumes that six different layers of an assistance system and its context will affect learning motivation, engagement, and well-being via the mediation of the three needs autonomy, competence, and relatedness defined in SDT (Deci and Ryan 1985) as well as through relationships between the individual layers. The respective layers are work domain variables, factors concerning the person, and job characteristics as described in the JCM (Hackman and Oldham 1980). The innermost layers concern the behavior, the tasks that achieve this behavior, and the interface with which the tasks are carried out. A general design strategy can be derived from the layer structure as well as from the meta-factors gamification and the elements defined in the ARCS Model of Instructional Design (Keller 1987).

While some of the theories included in the model are rather new, they mainly integrate the concepts of need satisfaction and qualitative differences in motivation from SDT, which have been empirically evaluated in various domains and settings. The assumptions about relations in the present model also build upon research findings from SDT and JCM, including their respective scales to measure need satisfaction and task design components. Additionally, the model allows individual variables from different theories such as JCM and METUX (Peters et al. 2018) to co-exist without the interference of constructs. This is due to its layered design, the moderator relations between the layers, and the mediation of SDT needs. Furthermore, the scope of layers from macro- and domain-related aspects down to smaller entities such as tasks and interface components allows for a structured development of applicable strategies in line with established design procedures.

6.2 Limitations

6.2.1 Omitted theories and concepts

The theories discussed in the present study were selected according to their belonging to one of the three research areas motivation in education, at the workplace, and in system design. This classification was chosen after a preliminary analysis of major research fields and was kept due to the fact that it provided the opportunity to explicitly include assistance systems and related research factors into the final model. However, two consequences of this choice are important to point out. First, some theories were not included as they have not been applied in the three areas. For instance, Berlyne's work on curiosity (Berlyne 1954, 1960) certainly is relevant for the design of systems that motivate operators to learn. However, it seems like this work has not been applied in education, work, or systems design, and therefore our search could not return it as a result. Fortunately, the important issue of curiosity still is represented in other theories included in the present article. For instance, it is related to the ARCS strategy of evoking attention, the concept of explanation seeking from Attribution Theory, and as well as Maslow's cognitive needs. In this way, it still can be considered in the model.

Second, from the theories and concepts found within the three areas, not all were presented in this article and even fewer were integrated into the model. This was done to keep it practically and empirically useful.

The model does not include theories on acceptance or adoption of the technology directly, such as the Technology Acceptance Model (Davis 1989) or its integration into a gamification framework (Herzig et al. 2015). First, acceptance of a technology can and should be created before its introduction into the workplace, for example by a user-centered design process. Second, the model describes strategies that ultimately increase the acceptance of the technology through its use by focusing on user experience and need satisfaction as core elements. Furthermore, the use of *BLAP*-gamification elements (Nicholson 2015) at the beginning of its introduction also addresses the issue of acceptance.

Of the gamification frameworks found during the collection of theories, none was integrated into the final model. First, while the concept of gamifying non-game elements is nothing new, the connection of different empirical results into a final validated framework has yet to be achieved. Including non-validated frameworks would diminish the empirical validity of the model. Therefore, gamification is used as a set of strategies which can be successful to achieve motivation in different settings and domains, but not as an individual factor in the model. This also enables flexibility in choosing appropriate strategies during the design process such as those presented by Nicholson (2015).

Another important factor not directly addressed in the model is the organization the assistance system will be implemented in. While the model includes the JCM variable of context satisfaction and assesses criteria relevant to the work domain, the organization per se is not included in the model factors as the latter are specifically concerned with the socio-technical system. Nonetheless, closely evaluating the goals and needs of the organization before implementing a new system is highly advisable (McDermott and Stock 1999; Wang et al. 2006).

6.2.2 Model design

A first limitation concerning the model design process is that the model was created by classifying theoretical theories and concepts according to their belonging to either motivation in education, the workplace, or system design. Another possible classification strategy would have been to select theories according to the part of motivation they focus on, meaning whether they are more concerned with cognitive, behavioral, or job-related components of motivation. Using another selection and classification strategy would most likely have resulted in different combinations of theoretical elements and, therefore, in a different model.

Second, the model is structured in such a way that different theories could be integrated and at the same time keep their internal factor relations. This was achieved using a layered design where associations between factors within a layer are preserved. In this way, the validity of the original theory is not compromised and only moderating or mediating effects are proposed between the layers. However, a side effect is that the model is practically useful but does not provide many hypotheses that are readily testable. Another possible model design could have been achieved by condensing the factors of different models into their essential components, comparing these components, and then integrating them into new constructs with proposed hypothetical relations between them. It was decided not to use this strategy as it would require to first evaluate each newly created component individually before relations between them could be assessed. Due to the fact that the model has not yet been evaluated, possible research scenarios will be presented in the next section.

Another topic that is not specified in the model is the type of assistance system. This was done to provide a wide range of possible strategies that can then be adapted to specific use cases. However, having a clear understanding of the kind of assistance a task requires and therefore the type of assistance system that is implemented will aid in tailoring strategies to best support learning. It can generally be said that assistance systems for fault diagnosis may be better suited to support learning because they require an understanding of the topic at hand, whereas systems that support memory functions or manual tasks, for example, are more dependent on cognitive capabilities and manual skills. However, the latter type of system can also benefit from certain strategies derived from the model such as feedback (Gorecky et al. 2011; Mostafa et al. 2012).

6.2.3 Model testing

In the present article, we developed a model but did not empirically evaluate it, yet. This is for two reasons. First, our main goal was a theoretical one: Asking what different motivation theories can teach us about the design of assistance systems. This goal is reflected in the extensive literature section that describes motivation theories from various research areas. In principle, it would have been possible to end at this point and only provide a brief, textual conclusion about the implications of these theories for the design of assistance systems. However, this would have been insufficient to specify how to apply these motivation theories, which requires a more thorough elaboration of the design recommendations that can be derived from them. The model addresses these issues by translating our findings on motivation theories into practical design strategies.

Second, testing the model is an extensive endeavor that requires multiple iterative rounds of scrutiny. In fact, it is a new line of research in itself. To perform a valid test, it would be necessary to design at least two assistance systems (one according to the model and one without it), implement them in the field, and evaluate their impacts on changes in operator motivation in a longitudinal study. Moreover, several additional studies would be needed to investigate individual aspects of the model in detail. Although such work certainly is valuable, it is far beyond the scope of a first step towards motivational assistance system design in industrial production.

Future tests of the model should evaluate its prescriptive value, asking whether a consideration of the strategies proposed by the model will lead to more motivational assistance systems. For instance, does it pay off to systematically analyze work domain variables, person variables, and job characteristics to derive motivating interface design strategies? Does a consideration of motivational affordances really lead to more integrated motivation? These and similar questions should be addressed in future work.

6.3 Theoretical implications

The design of the model warrants further research. It should be investigated to what extent the proposed theory-driven relations will lead to actual differences in learning motivation and ultimately measurable learning outcomes. These learning outcomes are not explicitly defined in the model to keep it general enough to be applied in different industrial domains. Depending on the domain, different outcomes could be desirable, such as learning transfer, performance results, or deep understanding of a certain subject. These distinct outcomes each warrant separate foci, and thus specifying them in the model would ultimately have made the model too convoluted to be practically useful. Therefore, general learning outcomes were chosen as the product of the model, which provides the opportunity to adapt the individual parameters to specific needs. Future works can build upon this global view and evaluate which kinds of learning

outcomes are best supported by the model. Some of these more specific outcomes are implicitly represented in the model already. For instance, letting users directly implement the newly gained knowledge will increase knowledge transfer (Cordeiro 1998). Also, providing precise and timely feedback informs users about the results relative to the wanted outcome, which in turn allows them to assess their current performance level and act upon that (Becker 1978; Lefevre and Cox 2016).

To further increase the practical usefulness of the model, specific situated motivational affordances in the context of assistance system design should be investigated. The proposed motivational structures in Szalma's Theory of Motivation and Human–Technology Interaction (2014) could be transferred into the relevant work domain context and it should be enquired which motivational affordances best support need satisfaction in their respective domain.

Another research question is the extent to which JCM factors act as moderators for learning motivation. The original model mainly concerns general motivation and does not explicitly distinguish between extrinsic and intrinsic motivation. Investigating whether the core characteristics and critical psychological states of JCM can be applied to the autonomy continuum of motivation defined in SDT will provide valuable insights for both the original theories and the present model.

Additionally, it is of interest which other moderators besides those outlined in the JCM may act upon the motivation to learn. The acceptance of work tools such as assistance systems could be playing a role, as well as an operator's personal goals outside of an organizational scope.

6.4 Practical considerations

One important factor of the model is the assessment of operators' skills and goals before the system is used. Only operators that already are experts on a subject will be able to adequately use certain motivational system aspects such as exploration (Jonassen and Grabowski 1993). If expertise is assessed before system use, the interface is able to provide more or less guidance depending on the user's skill level, for example via scaffolding (Hannafin 1992) or advice the user can choose to follow (Ross and Morrison 1988). This assumption has direct practical implications. When designing motivating assistance systems, users' attitudes and opinions should be at the center of design decisions. This can be implemented via user-centered design, which involves the end-user in the entire design process (for an overview see Abras et al. 2004). Placing users at the center of the introduction of new systems also helps in increasing acceptance.

Besides acceptance on a purely technical level, there also exists the issue of privacy concerns regarding the individual's data that is collected and stored. It should be noted that gamification elements if realized in the manner of challenges and levels, should only be present on the local device and not be accessible by the operator's superiors. This way, privacy concerns can be held at a minimum and further increase user acceptance.

The present model does not address societal and demographic changes. More and more young individuals work in industrial domains, and they are familiar with technological devices such as phones, and tablets, and touch screens. At the same time, there still is a large number of older workers, who are not as used to these devices and interaction concepts. Due to the fact that this is a general development in many vocations and not just specific to motivating assistance systems, this issue was not integrated as an additional factor in the model.

6.5 Other strategies of instilling motivation

Although the present study is mainly concerned with enhancing motivation to learn through the design of assistance systems, there are several other strategies organizations can use to instill such motivation. Organizational trainings provide a means of explicitly teaching the skills and knowledge needed to execute daily work tasks. However, in order for them to be successful, motivation has to be present before the training and the contents have to be repeated periodically. This is not feasible in every work domain. For instance, in the discrete processing industry many seasonal workers are employed who may not work in the same plant the next year so that the costs would not warrant the benefits of training effects. Another way of increasing motivation to learn is job enrichment so that operators gain more responsibility for their machine and are in charge of servicing and fixing it (Blanchard 2016). While certainly helpful to increase knowledge, this strategy is not applicable in every work domain. To increase motivation, classic measures such as rewards and punishments can be used. Such systems generally are low in cost and easy to implement, in line with gamification research. At the same time, they usually only provide short-term effects and come with the risk of thwarting need satisfaction. If actions are externally regulated without the operator's goals matching the company goals, motivation will be at its lowest (Gillet et al. 2013; Mitchell et al. 2012).

On the other hand, implementing a new assistance system with the inclusion of the respective operators is an expensive endeavor. While this implementation is certainly warranted, especially in the light of *Industry 4.0*, many small and medium-sized enterprises will not be able to afford this risk of implementing these kinds of new technology and interaction concepts. Therefore, the "classic" strategies of instilling motivation described in the previous paragraph will still be

in use for many years until further evaluated implementation strategies are readily available and more affordable.

6.6 Conclusion

The use of assistance system design to increase industrial operators' motivation to learn is a promising new socio-technical approach with possible benefits for individuals, organizations, and industrial domains. In the present article, we presented practically useful strategies derived from an integrated, theory-driven model, and discussed possible limitations and prospects of its application. In this way, the article describes the state-of-the-art and its possible implications for the design of industrial assistance systems, thereby proposing an open discussion about challenging topics for Industry 4.0. Further research is required to investigate and increase the validity and practicality of the model.

Compliance with ethical standards

Conflict of interest The authors declare no competing interests.

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