Rethinking Work in the Age of Robots: Insights from the Construction Industry

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***Abstract* — This research paper examines the transformative shift in the construction industry with the adoption of Construction 4.0 technologies, particularly robotics, and how these advancements impact the professional work values of construction personnel. The study employs a qualitative methodology, conducting semi-structured interviews with a diverse group of construction personnel, including both management and tradespeople, during a workshop where they interacted with construction robots.**

The effect of Construction 4.0 on professional work values in the construction industry has been insufficiently explored. The study provides new knowledge on the dual impacts of robot integration in construction, highlighting both the enhancement of certain professional work values and the challenges posed to others. Understanding these impacts is crucial for developing strategies that support both technological innovation and worker preparation.

The study addresses the following research questions: How do construction personnel identify and describe the positive and negative impacts of robotic integration on specific professional work values? In what ways do participants perceive robots altering workplace dynamics and interpersonal relationships within the construction industry? What strategies do construction personnel suggest or foresee as necessary to mitigate the challenges posed by robotic integration?

Using a qualitative research design, the study conducted semi-structured interviews with construction personnel who participated in a hands-on workshop with robots. Content analysis, incorporating both inductive and deductive coding, was used to identify key patterns and categories. Limitations include the small sample size, limited demographics, and the specific context of the workshop setting.

The integration of robots positively influences professional work values such as professional development, work productivity, mutual vision for work, control of work schedules, and work conditions by reducing physical strain and enhancing efficiency. Conversely, it negatively impacts values related to the interactive work environment, effective communication, sense of belonging, and job security, primarily due to reduced human interaction and fears of displacement. These findings highlight the critical need for industry leaders and educators to develop strategies that balance technological advancements with the preservation of positive work values. Comprehensive training programs, continuous professional development, and fostering an inclusive, adaptive work culture are essential. This study advances our understanding of the human side of technological integration and provides actionable recommendations for creating a balanced and resilient future workforce.

Keywords—Professional Work values, Technology Studies, Civil Engineering, Human-Robot Interaction, Lifelong Learning

I. INTRODUCTION

In the dynamic landscape of civil engineering, the winds of change blow strong as the industry undergoes a profound transformation fueled by the technological frontier of Construction 4.0. Defined by its integration of digital technologies like artificial intelligence, robotics, and the Internet of Things [1], Construction 4.0 heralds a fundamental reimagining of construction processes, organizational structures, and professional roles [2]. Despite its futuristic allure, the journey towards the full realization of Construction 4.0 may seem distant, yet the imperative to understand its implications on the incumbent workforce is palpable. This understanding is pivotal in preparing present and future construction personnel to navigate the shifting sands of their industry [3].

Central to this preparation is the comprehension of how this technological wave might reshape the foundational values guiding work behavior. Work values, intricate belief systems dictating decisions and actions in the professional sphere [4], stand as crucial precursors to facets like performance, satisfaction, and the propensity for lifelong learning. As such, the potential impact of Construction 4.0 on these values, particularly with the introduction of robotics into the construction fold, warrants meticulous investigation.

In pursuit of deeper insights into this dynamic interplay, this paper endeavors to contribute to the burgeoning discourse on the influence of emerging technologies on professional work values. By elucidating the nexus between Construction 4.0 and the values shaping workforce behavior, this research not only enriches scholarly understanding but also sets the stage for proactive measures to integrate innovative technologies into the fabric of civil engineering practice.

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II. Background

A. Shifting Work Practices in Construction 4.0

One of the major innovations of Construction 4.0 is robots in the workspace. It is envisaged that humans and robots will work side-by-side, with robots bound to change the very nature of construction work [2]. While several studies have focused on various aspects such as robot types, key concepts, challenges, and opportunities facing construction 4.0 [5], [6], [7], [8]; relatively underexplored is the training and preparation of civil engineers and construction personnel for robots in their workspace [9]. This lack of emphasis is particularly concerning, as these changes – to work content, work organization, management, and other organizational factors – affect how construction personnel will perform at work. With this continuous transformation, it is necessary to develop highly skilled individuals, capable of applying technologies while navigating future changes and their challenges.

B. Emerging Work Roles and Skills Disparity

Numerous studies have explored the impact of robotics on work content and organizational dynamics, particularly in redefining job roles, revealing that the widespread integration of robotics has significantly altered these dynamics by introducing specialized roles and competencies, reducing reliance on traditional supervision, and intensifying job polarization through expanding skill disparities across the workforce [10], [11], [12], [13], [14], [15], [16]. The introduction of robots has reshaped the construction process by creating new job roles focused on supporting robotic operations in the workspace, leading to changes to current job roles due to the different skills and competency requirements [10], [14]. Studies indicate the possibility of job polarization with the reduction of middle-level skilled jobs and consequent increase in the low- and high-level skilled jobs linked to direct support of the robots [15], [16]. Other views, in parallel, are that the low-level skilled jobs not in alignment with the robots in the workspace will be diminished, calling attention to the need for personnel to be prepared for the upcoming changes [11], [12], [13]. The influence of robots is not limited to just non-managerial personnel; one study presents that robots, by reducing mistakes and errors at work, will necessitate a decrease in the current demand for traditional supervision and consequent management-level employees [15]. These studies collectively underscore the urgent need for reevaluating worker preparation for these impending changes, highlighting a critical shortfall in current workforce training and development. This study aims to address this shortfall by focusing on work values and the evolving dynamics between human workers and robots, offering insights that are essential for preparing a future-ready workforce.

C. Investigating Work Value Shifts

Values are essential constructs that significantly influence human behavior and decision-making processes. Schwartz and Bilsky describe them as "concepts or beliefs, about desirable end states or behaviors, that transcend specific situations, guide the selection or evaluation of behavior and events, and are ordered by relative importance" [7, p. 551]. These values play a crucial role in decision-making by acting as guiding principles. They help individuals evaluate the desirability of different outcomes and choose actions consistent with their goals and values. Consequently, examining work values is crucial not only for gaining psychological insights but also for fostering societal progress, as it enhances our understanding of the motivations behind human actions and guides them toward more cohesive and efficient work outcomes. [17].

In the construction industry, understanding work values is particularly crucial for comprehending workers' behaviors and decision-making processes. These values are pivotal in shaping decisions such as entering and staying in the construction industry and determining their behavior through job satisfaction. Previous research has explored the work values of construction personnel, developing strategies that direct and modulate their behavior and decisions [18], [19], [20], [21].

Therefore, this study focuses on how the introduction of robots will impact the professional work values that guide construction personnel in their daily activities. Specifically, it answers the following research questions: How do construction personnel identify and describe the positive and negative impacts of robotic integration on specific professional work values? In what ways do participants perceive robots altering workplace dynamics and interpersonal relationships within the construction industry? What strategies do construction personnel suggest or foresee as necessary to mitigate the challenges posed by robotic integration?

The findings will help formulate strategies to equip workers for the transition to Construction 4.0, ensuring they are prepared for changes in their professional environment. By addressing these questions, this study aims to provide valuable insights into the evolving dynamics between human workers and robots, ultimately contributing to a more adaptive and resilient workforce.

III. Conceptual Framework

To address the research questions, this study utilizes a conceptual framework elucidated by Bae et al. [18], [19], which categorizes values into three dimensions: professional work values, professional cultural values, and professional work-life values. These dimensions serve as a foundation for understanding the work values of construction personnel and their significance in career development within the construction industry.

Within this framework, professional work values serve a central role, guiding individuals' career trajectories and influencing their decisions within the construction sector. For instance, prioritizing professional development may lead individuals to seek roles offering opportunities for skill enhancement and advancement. Additionally, fostering values such as lifelong learning can facilitate adaptation to emerging technologies and industry innovations.

The professional work values identified for construction personnel encompass both interpersonal and intrapersonal dimensions, reflecting individuals' beliefs and expectations regarding their roles in the industry. These values include sense of belonging, professional development, effective communication, interactive work environment, optimization of work productivity, mutual vision of work, and control of the work schedule [19]. These values are defined in Table 1.

In this study, we extend the Bae et al. framework by investigating how the integration of robotics impacts professional work values, workplace dynamics, and job security of construction personnel; and what strategies can be implemented to mitigate these impacts. By examining the interplay between technological innovation and value systems, we aim to deepen our understanding of the evolving dynamics within the construction industry and inform strategies for workforce development and adaptation in an era of rapid technological change.

Table 1. Professional work values of construction professionals [18], [19]

Professional Work Value	Definitions
Mutual Vision for Work	Sharing a common goal for work with coworkers and the employer.
Control of Work Schedule	Having more flexibility in their work schedule.
Sense of Belonging	Having a sense of involvement in their company and receiving acknowledgment of their accomplishments.
Professional Development	Having more opportunities for advancement and structured professional development programs.
Effective Communication	Having an efficient communication system among different levels and branches of a company.
Interactive Work Environment	Having a family-like environment in which employees build positive work relationships.
Optimization of Work Productivity	Having autonomy to improve the efficiency and effectiveness of work operations.

IV. Methodology

The study aimed to capture the participants' subjective perspectives and interpretations. Thus, a qualitative research design was adopted in this study. A qualitative approach is recommended as a means to enrich our understanding of humans working with technology like robots [22]. Thus, this approach aligns with our research questions involving the experience of participants as construction personnel and their interaction with robots during a workshop.

A. Context and Participants

This study is part of a broader project aimed at exploring partnerships between humans and robots. The project included a two-day workshop where participants interacted with construction robots through three distinct sessions. The first session featured a video presentation of the envisioned partnership with the robots. In the second session, participants interacted with a virtual robot performing drywall installation. The final session involved direct interaction with a physical robot, including tool transfer and handling. For a more detailed description of the robots used in these sessions, see [23], [24].

The workshop participants consisted of construction personnel in the Midwestern region of the United States. A demographic survey revealed that all participants identified as White males, with positions in middle-level management (M.L.M.) and low-level management (L.L.M.), as well as tradespeople (T). Participant I.D.s and demographics are detailed in Table 2.

Table 2. Participant demographics

I.D.	Age	Job Title	Category of Personnel	Years of Experience
A	51	General Superintendent	M.L.M.	35
B	36	Foreman	L.L.M.	17
C	31	General Trades Superintendent	M.L.M.	5
D	54	General Foreman	L.L.M.	37
E	46	Piping Labor Superintendent	M.L.M.	26
F	34	Dry Wall Finisher	T	15
G	45	Instructor / Coordinator	T	25
H	32	Carpenter	T	8
I	53	Operations Managers	M.L.M.	33
J	39	BIM Manager	T	19
K	34	Detailer	T	10
L	30	Project Manager and Estimator	M.L.M.	8

B. Data Collection

Data was collected through semi-structured interviews. Interviews took place before and after each session in the workshop, each lasting between 60 to 90 minutes. Participants were asked to reflect on their experiences in the workshop. Subsequently, they were asked how they perceived the inclusion of these robots in their workspace would influence their work values. Example questions included: "What are your beliefs, that should be satisfied based on your participation in your job roles?", "How, if at all, do you think introducing such robotic technology will impact the professional work values you identified?" and "How do you feel the use of these robots will change the work environment?" Interviews were audio-recorded and transcribed verbatim. These interviews were all conducted in alignment with the institution's I.R.B. (Institutional Review Board) practices.

C. Data analysis

The qualitative nature of the data necessitated the application of qualitative content analysis to examine the audio recordings and transcribed data [25], [26]. The unit of analysis was specific phrases or sentences participants use to describe their views. Dedoose, a web-based application for qualitative data analysis, was chosen for its cloud-based nature, which facilitates collaboration among research team members.

This analysis comprised two distinct coding processes: a deductive coding method employing the conceptual framework by Bae et al. [18], [19], and an inductive coding approach that

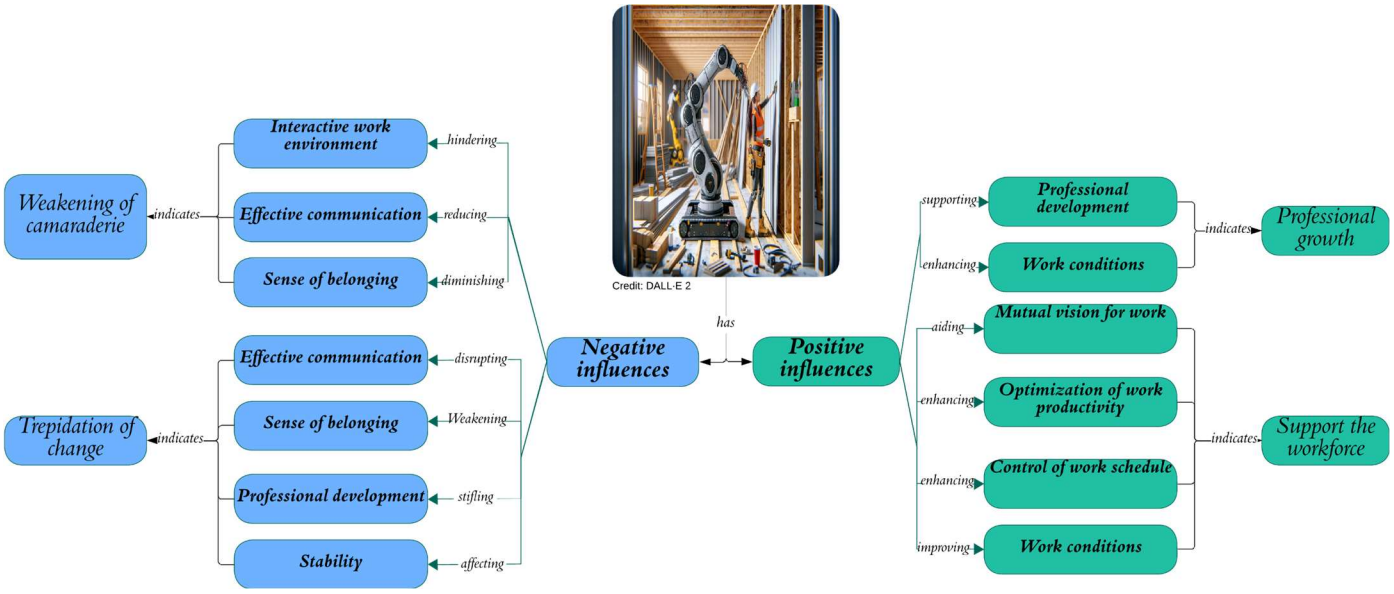

Figure 1. Professional work values of construction workers and the influence of the integration of robots.

allowed for the emergence of codes from the data [27]. Initially, a codebook was developed based on the conceptual framework. These codes underwent peer debriefing to evaluate the trustworthiness of the coding process. During the peer debrief, an intercoder agreement was reached regarding the codes, their definitions, and sample quotes. These codes were categorized to address research questions, initiating discussions within the research team to extract insights from the categories relating to the perceived influence of robots on the professional work values, workplace dynamics, and job security of construction personnel.

D. Trustworthiness and Positionality

In qualitative research, the constructivism philosophical perspective approach is employed, wherein researchers construct meaning through their interpretation of the data [28]. Peer debriefing was applied to ensure the trustworthiness of the findings and that the researcher's independent interpretation was in alignment with the data [29]. This process was conducted through the discussion of the memos, codes, and categories.

Acknowledging our roles as interpreters of the data, we recognize that our positions, identities, and experiences may shape how we view the data. The analysis was conducted by a graduate student and a faculty member at a top-tier research institution in the U.S.A. The first author acknowledged his limitations in the lack of shared experiences with the participants. His construction experience is not situated within the same context as the study participants or within the United States. However, the second author brings her unique perspective and significant academic and industry experience to the research, particularly in the context of the construction industry.

V. Findings

The use of the Bae et al. [19] conceptual framework to analyze the data showed that participants believe integrating robots into their workspace can have either a positive or negative influence on their professional work values. Figure 1 presents a structured overview of these values, and how participants perceive integrating robots will influence them and their work. The subsequent sections provide a more detailed explanation of the findings.

A. Positive influence

Participants believed that the assistance from robots, along with the opportunities for development and advancement, would positively impact certain professional work values. These professional work values include professional development, optimization of work productivity, mutual vision for work, control of work schedule, and work conditions.

1) Support for the workforce

Support is described in this study as robots aiding in enhancing safety, improving work conditions, fostering better work-life balance, and also aiding in goal achievement for both management-level personnel and tradespeople. Many participants in their responses perceived that the robot's support of the construction industry would positively influence some of their work values. These values include work conditions, control of the work schedule, optimization of work productivity, and a mutual vision of work. For the work condition, described as having a work environment that is safe with minimal physical strain, participants highlighted the importance of this value, with an operational manager saying:

> I think it would help, especially in our trade. Retirement usually happens around age 62, and you do not see many people out there at that age still working. It's not just about knowing how things are done but also the repetitiveness of the tasks, like hanging and finishing drywall. It's all very repetitive. By their mid-50s, most are done with all the lifting and bending involved. So, anything that could help extend their careers would be beneficial. (Participant I)

The manager highlights the physical challenges workers face in the construction industry, particularly the toll of repetitive and strenuous tasks like drywall installation. He emphasizes the need for measures to reduce these physical demands, which could help extend workers' careers and delay their abrupt or early

retirement. A superintendent echoed this, like many other participants in the workshop, saying:

> I've been doing this for 25 years, and the wear and tear on our bodies is a big issue … I've had two surgeries: I tore my bicep about three years ago and my rotator cuff last year. Definitely, the repetitive tasks take a toll. If the robot could do it (Participant E).

Drawing from his personal experience, the superintendent voiced concerns about the physically demanding aspects of construction work, highlighting the toll it takes on the body as well as the associated safety risks.

Participants perceive that integrating these robots aimed at reducing the physical toll on construction workers and possibly reducing the hazards on construction sites would positively influence the value of having a safe work environment with minimal physical strain. As an example, a superintendent said:

> To enhance safety, I was explaining to your team that I drill many holes in concrete to install anchors for hanging pipes. Now that it's known that silica from concrete can cause cancer, many states won't allow you to drill without precautions. However, even with precautions, drilling is tough on the shoulders, especially when you're making large holes in concrete. If a robot could drill the holes and then set the anchors, that would be amazing, because most of my guys get worn out by midday. Drilling overhead and then having to hammer in the anchors really wears out everyone's shoulders. It's a tough job. If a robot could take over, it would relieve the physical stress on the workers' shoulders and remove them from the silica exposure (Participant E).

Reflecting, the superintendent, although uncertain of the full capability of the robots, perceives, like many other participants, that the robots will perform the hazardous aspect of the job and reduce the physical demands.

In addition to the direct implication of the robot through the work conditions, participants perceived the robot as supportive in other ways, such as accomplishing their tasks. This perception varied across participant groups, such that management-level personnel foresee increased profits and more control over the work process and schedule, which could enhance performance. At the same time, tradespeople anticipate support in easing the physical demands of their tasks and better work-life balance. As an example, a foreman shared:

> From a supervisor's perspective, increasing productivity, reducing mistakes, and boosting profits. From both a buildability and company management standpoint, the only potential downside is the initial investment in the machinery. If these improvements can be achieved, they should lead to higher profits, which is always beneficial. (Participant B).

Another superintendent commented, "You could weed out some of those more troubled employees and not have to worry about it because you'll have that robot you trust." (Participant C). A tradesperson commented, "Just being able to do things for a longer period of time physically would definitely help you feel better." (Participant K). This support is perceived by the various participants according to their job roles. The foreman perceives more control and better productivity and efficiency with the introduction of these robots; they perceive that the robot will assist them in improving efficiency and productivity and in accomplishing their shared vision and goals. Consequently, these supports are perceived to positively influence the mutual vision for work and the optimization of work productivity.

Concluding, the participants perceived that the supports, as attributed to the robots, will improve their scheduling, providing them with more work-life balance and the opportunity to engage in more productive and mentally stimulating aspects of work rather than the physical and monotonous aspects of work. As an example, a tradesperson said,

> I would assume they [robots] would be able to work 24 hours a day as opposed to humans not being able to, which would allow somebody to have a little bit more work-life balance, (Participant G).

This tradesperson notes that the support provided by the robot will enable them to achieve a better work-life balance.

2) Professional growth

Participants in this study believe that integrating robots into the workplace will not only provide support but also enhance their professional growth, influencing some professional work values. As described in this study, professional growth is defined as continuous skill development and inclusive practices aimed at expanding opportunities for all, irrespective of background. Participants in the workshop perceived this to influence both deductive values, such as professional development, and inductive values related to work conditions and workforce diversification.

Participants in this study emphasized that new skills and competencies will be required with the integration of robots in the construction space. They believe acquiring these new skills and competencies will open avenues for development and career advancement, allowing them to assume new roles. Thus, highlighting the need for lifelong learning to keep up with technological advancements. These were especially pronounced in participants who indicated values like versatility (that is, being engaged in various construction tasks). As an example, a foreman explained:

> I would have to do some learning myself and become more efficient and proficient with the robots. I mean, if this technology is going to continue to advance, shouldn't I also advance with it? (Participant D).

This foreman calls attention to the continuous learning process required to keep up with the changes of the times. Another participant, a BIM manager, reflected on the opportunities integrating robots may provide for new roles, saying: "Somebody has to manage all the BIM work [referring to controlling the robot] ... So, it just opens doors to other opportunities in construction." (Participant I). This BIM manager points out the opportunities for new job roles that will come about with the inclusion of robots in the workspace, especially in the context of his current job role associated with BIM and new construction technology.

Several participants echoed the desire for more development and training opportunities when asked about their expectations from their interactions with robots in the workshop. They were eager to learn more, requesting additional workshops, more "hands-on" experience with these robots, and a deeper understanding of the "back-end stuff," which includes repairs, maintenance, and programming of the robots, as well as skills

and knowledge to troubleshoot issues in these technologies on construction sites without external help. These requests reflect the participants' positive attitudes towards the new technology in this workshop, emphasizing their commitment to developing themselves and embracing lifelong learning.

B. Negative influence

Participants expressed that integrating robots into the workspace could lead to changes that negatively affect professional work values. They associated these negative impacts with alterations in the construction process, required competencies, and relationships between coworkers. The values they believed would be adversely affected include an interactive work environment, effective communication, a sense of belonging, professional development, and job security.

1) Trepidation of change

As described, trepidation of change is the concern about introducing robots in the workspace, including fears related to job security, required competencies, and adaptation challenges. In reflecting on their experiences, participants pointed out several changes that could result from integrating these robots, which could negatively influence their values. These changes include the new competency requirements, changes to the communication processes, and limited interactions with coworkers. A manager noted the change, saying:

> The actual challenges it will bring to the worker. They have to adapt to learning the new technology and how to work with it [robots]. A lot of guys who have done it for a long time are going to resist any changes. (Participant I).

The manager expressed concerns about the adaptation integrating robots would require of construction workers, arguing that this would be a challenge that would face pushback in changing the status quo. Participants called attention to the specific changes that the construction industry will make, such as changes in the very nature of communication methods. For instance, a participant expressed concerns about language differences, saying, "You're probably going to program a robot to use standard terms, like calling a piece an 'elbow' instead of using our everyday slang. Does this mean it replaces it?" (Participant B). Another participant highlighted the need to learn new ways to communicate: "I am just going to talk to the robot in the right program, computer language, or robot language. So, we have to learn how to speak that language." (Participant D).

Participants expressed concerns about these new competencies being mandated, viewing them as either "adapt or perish." Participants fear these changes might push them out of the industry, reducing their sense of belonging with their coworkers. As a participant said, "You know the owners, the managers, and the engineers. Also, the workforce will either have to adapt, adopt, or be displaced." (Participant J). Given the critical nature of a sense of belonging in construction, another participant stated, "Belonging will be affected most because it depends on where you are in the program. If you're lagging or just not keeping up, you might lose your sense of belonging." This leads to fears regarding job security: "Some people might be scared of it. Some might fear being displaced," (Participant D) noted a participant regarding the fears of job security with the integration of robots.

Overall, participants perceive that professional work values such as sense of job security, professional development, and having an interactive work environment will be negatively influenced by the integration of robots in the workspace.

2) Weakening of camaraderie

The weakening of camaraderie, as described, is the limiting of workplace relationships due to isolation and communication challenges. There is a specific concern about the erosion of camaraderie among construction workers.

Construction work, often built on familiar relationships and interactive engagement, is described by participants as a "tight-knit" or "mom-and-pop" workplace. However, it is perceived that robots will limit interactions with other workers, reducing opportunities for the interactive engagement necessary to foster such relationships. As an example, a participant explained: "So yeah, it'd be boring if you were stuck on the job site, with just you and the robot all day without human interaction" (Participant E). This comment expresses concern about interactions with robots devoid of humans. Reflecting on the nuances of their interaction with other workers, a participant commented:

> When you're dealing with someone daily, you have the feelings and the mutual conversations. You're now going to take that out of the equation. You're working alone, so you better be comfortable dealing. With just a machine. (Participant A).

The level of personal communication and interaction will be eroded in the construction industry: "It (robots) still interacts with you, but not in speech form. I think a person would make eye contact and use body language. I believe the robot would be more textual and visual." (Participant K)

Overall, construction work has flourished due to workplace relationships and interactions between workers. However, workers believe that integrating robots into the construction environment will limit opportunities to build such relationships. This limitation stems from the isolation between workers interacting more with robots and less with each other.

VI. Discussion

Construction 4.0 is poised to transform the construction industry, significantly affecting both operational practices and the workforce [2], [14]. This transformation necessitates a workforce adept at navigating these changes [30]. This study contributes to preparing the workforce for construction 4.0 by exploring the influence of the integration of robots on the professional work values of construction workers. Using Bae et al. [19] professional work values conceptual framework, this study identified professional values that were either positively or negatively influenced by integrating robots in the construction workspace. The participants in the study alluded to the professional work values as identified in Bae et al. [19] conceptual framework—sense of belonging, professional development, effective communication, interactive work environment, optimization of work productivity, mutual vision of work, and control of the work schedule—highlighting the importance these values in their work lives and decision-making relating to their job roles. The findings also revealed other professional work values not captured in the Bae et al. [19] conceptual framework. These emergent values include a sense

of job security and a safe work environment with minimal physical strain.

The findings of the study suggest that the professional work values; professional development, mutual vision for work, optimization of work productivity, control of work schedule, and work conditions may be positively influenced by the integration of robots. While the participants reflect that other professional work values, such as Interactive work environment, sense of belonging, professional development, effective communication, and stability, may be negatively influenced by the integration of robots. Furthermore, the findings identify and describe these values as influenced by four factors: the support robots provide to the workforce, the opportunities for professional growth, apprehensions about the changes robots will bring about, and a decline in camaraderie among construction workers.

These findings aligned with the results from Smids et al. [31], which found that integrating robots in the workspace could either diminish or enhance the meaningfulness of work, presenting as an opportunity or threat to the aspects of meaningful work — pursuing a purpose, social relationships, exercising skills and self-development, self-esteem, and recognition, and autonomy. For instance, similar to our findings on sense of belonging and interactive work environment, Smids et al. [31] present the integration of robots as a threat to social relationships, diminishing the sense of belonging. For the opportunities, Smids et al. [31] present the positive outlook of integrating robots in exercising skills and self-development, aligned with this study's findings on professional development. Similarly, research in manufacturing, found that job security, job change, new jobs and opportunities, and management concerns were critical factors to consider when integrating robots into the workplace [31], [32], [33]. This aligns with the findings of this study, where participants in construction settings expressed enthusiasm about new jobs and opportunities, improved working conditions, and increased productivity while also expressing concerns about job security, job change, and management concerns about training and preparing a workforce for working with robots.

The integration of robots has dual effects on job availability, influencing both job security and professional development [10], [16]. Specifically, from the findings, while the presence of robots diminishes workers' sense of job security, it simultaneously enhances professional development by creating opportunities for advancement. This finding aligns with previous research suggesting that robotic integration reshapes the construction industry by introducing new roles for workers [14]. Studies indicate the relationship between robot integration and employment as either positive or negative [10], [15], [34], [35]. It can be attributed to job polarization with the elimination of some job roles like middle-skill jobs –due to the need for high-skilled workers not replaceable by robots or automation and low-skilled workers -- [15], [16] or managers [15] -- due to the requirement of less supervision of employees. Nevertheless, Chung and Lee's [36] exploration of the manufacturing sector from 2005 to 2016 identifies a pattern: the early stages of robotic deployment typically decrease employment, with the later stages seeing an uptick in employment. This shift from the early to later stages can be argued to be the phase where workers engage in upskilling to become competitive with the new workplace technologies. This transition reflects a need for a skilled and competent workforce prepared for robotic integration's long-term impacts and opportunities in the industry.

The integration of robots into workspaces necessitates the reskilling and upskilling of the workforce, a thread consistently highlighted in previous studies [3], [37], [38]. As these technological advancements alter traditional roles, employees must become adept at acquiring new skills and competencies to remain effective and relevant. Prior studies underscore the importance of hands-on experience and direct interaction with robots, emphasizing that these are critical to effective learning and adaptation [37], [38]. Participants in this study have expressed a significant need for more practical engagement with robotic technologies. Furthermore, a comparative review of the literature indicates that this aspect of workforce training is relatively underexplored, suggesting a pressing need for further research [37], [38].

A major concern of participants in this study was the negative impact the integration of robots might have on their professional work values, such as sense of belonging, interactive work environment, and effective communication. Construction is currently a very social job, with participants in this study reflecting on enjoying the interactions with their coworkers on-site. The integration of robots posed a threat to this social environment, leaving the participants concerned that they may feel isolated and alone while working with robots [31]. Studies are currently exploring the application of social robots to combat workplace isolation [39], [40] and improve communication [41]. This calls for more research, and design considerations needed in the development of construction robots to mitigate workers' concerns regarding interaction in the construction industry.

VII. Implications

The findings of this study underscore several critical implications for lifelong learning within the construction industry. Firstly, it is imperative for students and construction workers to adopt a proactive approach to their professional development. This includes actively seeking opportunities to acquire new skills and adapt to emerging technologies such as robotics. Embracing a continuous learning mindset will ensure they remain competitive and capable in an evolving industry landscape.

For educators and industry leaders, the study highlights the necessity of integrating personal work values into the design and implementation of training programs. It is essential that these programs not only impart technical skills but also address the professional work values that are important to construction workers, such as a sense of belonging, effective communication, and job security. By doing so, training initiatives can more effectively support workers in navigating the changes brought about by Construction 4.0 technologies.

Furthermore, industry leaders should foster environments where technological advancements are balanced with workers' well-being and professional fulfillment. This involves transparent communication about the benefits and challenges of

new technologies, as well as providing support systems that help workers adjust to new roles and responsibilities.

In summary, the implications of this study call for a holistic approach to workforce development in the construction industry. This approach should prioritize continuous learning and adaptability, while also ensuring that the integration of new technologies respects and enhances the professional values of construction workers. Through comprehensive training programs and supportive work environments, the construction industry can successfully navigate the transition to Construction 4.0, benefiting both workers and the broader industry.

VIII. Limitations

It is important to note that the participants of this study were construction workers who intentionally chose to attend a workshop on new construction technology and robots. Therefore, they may have entered this study with a more positive view of robots and not accurately represent the perceptions of the entire construction workforce, or those who did not choose to attend the workshop. Additionally, this study has a small sample size, represents a narrow demographic, and does not specifically address the managerial aspects of construction.

IX. Conclusion

The construction industry is at the cusp of a transformative era with the advent of Construction 4.0 technologies, particularly robotics. This study has illuminated the profound impact these technologies have on the professional work values of construction workers. By examining how these values are influenced by the integration of robots, we have gained valuable insights into both the positive and negative ramifications of this technological shift.

The findings reveal that while robots can significantly enhance professional development, optimize productivity, and improve work conditions by reducing physical strain, they also pose challenges to the interactive work environment, effective communication, and workers' sense of belonging and job security. These impacts underscore the complexity of technological integration within a traditionally human-centric industry.

Future research should focus on longitudinal studies with more diverse participants to monitor the long-term impacts of robot integration on the professional work values of construction workers. Investigating the evolving dynamics over time will provide deeper insights into how workers adapt to technological changes and the sustainability of both positive and negative impacts identified in this study. Additionally, exploring diverse demographic groups and different construction environments will enhance the transferability of findings and uncover potential variations in responses to robotic integration. Research should also delve into developing and testing intervention strategies that can mitigate negative impacts, such as fostering a sense of belonging and improving communication in a technology-enhanced workspace. Finally, interdisciplinary studies involving collaboration between engineers, psychologists, and educators can create comprehensive frameworks for integrating robots in a manner that optimally balances technological advancement with human-centric values in the construction industry.

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XI. Reference

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