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KWReq: A Novel Tool for Assessing the Knowledge Work Demands of Higher Education Graduates

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Abstract

Due to the absence of suitable questionnaires for capturing the evolving demands and conditions of highly educated professionals, we created a new German-language instrument targeting knowledge work. Grounded in theory, we identified three fundamental aspects of knowledge work: novelty, complexity, and autonomy. To operationalize these dimensions, we conducted a multi-step development process involving higher education graduates, which included a cognitive pretest, an initial quantitative study, and a replication study. From an original set of 173 items, the questionnaire was refined to 22 items. Confirmatory factor analysis and structural equation modeling confirmed that the instrument reliably and validly assesses novelty (4 items), complexity (9 items across three subdimensions), and autonomy (9 items across three subdimensions). An English version has been prepared; however, its empirical validation and potential further refinements are suggested as directions for future research.

Keywords: Questionnaire development, Higher education graduates, Job requirements approach, Novelty, Knowledge work, Autonom, Complexity

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Introduction

Research output has expanded dramatically over the past several decades. Scientific publications grew from 455,315 in 1991 [1] to 733,305 in 2002 [2], reaching 1,270,425 by 2014 [3]. This expansion is not limited to knowledge creation alone but extends to the entire knowledge ecosystem—including industries involved in knowledge production, infrastructure, management, and dissemination—which has seen significant growth in both employment and economic contribution [4, 5]. Meanwhile, traditional production factors such as labor and capital have diminished in relative significance, whereas knowledge and information have become central drivers of economic activity [6, 7]. For instance, software production costs primarily reflect high-skilled labor expenditures, highlighting the pivotal role of knowledge carriers [6]. Additionally, digitalization and other technological advancements have elevated the importance of knowledge across sectors, creating more complex work tasks [6, 8]. These developments toward a knowledge-driven economy necessitate adjustments in enterprise management, workforce planning, and educational systems [9, 10].

Higher education institutions play a critical role in equipping students for professional life. In Europe, the Bologna Process has reinforced the focus on employability, making it a central objective of higher education over the past two decades [11-13]. Consequently, universities must align curricula with evolving labor market demands, analyze the skill requirements of graduates, and adapt accordingly [14, 15].

Traditionally, the demand for higher education qualifications was inferred from macroeconomic indicators, such as economic growth, income-education relationships, or workforce composition by educational attainment [16-18]. Graduate shares were often used as proxies for knowledge intensity in economies, firms, or occupations [14] and remain part of national assessments of research and innovation, including German reporting [4]. Yet, such indirect measures do not capture the specific tasks performed by highly qualified employees, nor do they adequately assess knowledge work. A more precise understanding can be obtained through a “task-based approach,” which focuses on the actual activities involved in a job [14].

While knowledge work exists across occupational groups, it is particularly prominent among higher education graduates [8, 14, 19]. Given its growing role in modern economies, tools that measure knowledge work in graduate employment can provide deeper insights into the interplay between higher education and labor market outcomes.

Existing instruments in German have collected data on job tasks, some targeting graduates. For example, Braun and Brachem [20] designed a comprehensive survey covering nine dimensions of generic job-related activities—including work planning, team promotion, foreign language communication, physical effort, and autonomous task management—operationalized with 49 items. Although detailed, the instrument does not explicitly focus on knowledge work, although some items relate to aspects of it. The REFLEX project [21] employed a shorter, 29-item survey assessing professional expertise, flexibility, innovation, knowledge management, and human resource mobilization in graduates [15]. While economical, it does not adopt a task-oriented perspective, instead asking graduates to self-assess job-required competencies.

Task-based instruments targeting the general workforce include Matthes *et al.* [22], who developed a 48-item questionnaire capturing analytical, communicative, manual, complex, and autonomous tasks, and the OECD’s PIAAC study [23], which collected data across 11 task clusters in 39 countries. These tools, however, are often lengthy and primarily designed for diverse skill populations, limiting their ability to detect subtle distinctions among highly educated employees.

To address these gaps, we developed a new German-language instrument designed specifically for higher education graduates, emphasizing knowledge-intensive tasks. The instrument is theory-driven, concise enough for multi-topic surveys, capable of differentiating among graduates, and meets psychometric quality standards.

This paper details the development and evaluation of the instrument. Section 2 outlines conceptual foundations and identifies three dimensions of knowledge work. Section 3 describes the construction process, including cognitive pretesting and a quantitative development study. Section 4 presents reliability and validity analyses, drawing on data from both the development study and the DZHW graduate panel survey. The paper concludes with a discussion of findings, limitations, potential refinements, and practical applications of the instrument.

Conceptual Framework

Measuring job requirements

To capture the skill demands of higher education graduates, our study draws on the Job Requirements Approach (JRA), a method widely applied in both national and international surveys, including the UK Skills Survey [24], PIAAC [25, 26], NEPS [27], and the DZHW graduate panels [20]. The essence of the JRA is that job requirements are best understood by examining the tasks employees perform. This approach assumes that the activities individuals carry out reflect the actual demands of their roles and that employees themselves are the most reliable informants on the responsibilities and skills their jobs entail [20]. By focusing on observable work activities, the JRA not only provides a profile of job demands but also offers an indirect measure of the competencies needed, potentially reducing bias compared with direct self-assessments of skills [20].

Understanding knowledge work

Knowledge work has been conceptualized in multiple ways across disciplines, resulting in a variety of definitions without a universally agreed-upon meaning [28-30]. Early frameworks drew a simple distinction between mental and manual labor, but this binary fails to capture the nuanced nature of knowledge work, as even physically oriented tasks—such as a surgeon performing a complex operation—can involve high-level knowledge application [6]. Modern conceptualizations recognize multiple dimensions.

Hube [6] emphasizes complexity and novelty, defining knowledge work as “mentally objectifying activities” that involve engaging with novel and intricate processes or producing innovative results (p. 61, our translation; see Sobbe *et al.* [31] for an English summary). Hermann [32] similarly highlights that tasks become knowledge work when they are sufficiently unfamiliar or complex that an individual cannot rely solely on prior knowledge, necessitating the use of external expertise or the generation of new understanding (p. 214, our translation). Haner *et al.* [33] extend this model by adding autonomy as a critical dimension, proposing a framework that considers complexity, novelty, and autonomy together. They empirically differentiate four types of knowledge work, with the most narrowly defined form characterized by frequent engagement with complex and novel tasks, a high degree of independence, and continuous updating and refinement of knowledge ([33] pp. 19–25).

For the purpose of our survey, we integrate these perspectives. Our conceptual model identifies three pillars of knowledge work—novelty, complexity, and autonomy—drawing on Hube [6] and Hermann [32] while incorporating autonomy as suggested by Haner *et al.* [33].

Novelty
Novelty, as discussed in the literature, can relate to either the tasks themselves or the outcomes they produce [6, 32].In our instrument, we focus on the novelty of work outcomes. This choice allows us to streamline the questionnaire while targeting the most cognitively demanding aspect of knowledge work, as producing new results typically requires higher-level thinking than merely encountering a new task.

This dimension overlaps conceptually with creativity and innovation, terms frequently used interchangeably [34]. Creativity generally refers to the generation of ideas that are both original and useful [34], whereas innovation extends beyond ideation to the implementation or practical application of those ideas, often resulting in new or improved products, services, or processes [34-37]. In our framework, novelty is operationalized as innovative work behavior, a concept widely explored in prior research (e.g., de Jong and den Hartog [38]; Janssen [36]; Rehman *et al.* [39]; Scott and Bruce [34]).

Complexity
Complexity in organizational and work research has been examined at multiple levels, including systems, organizations, products, jobs, and individual tasks [40], leading to a variety of definitions [41]. Despite differences, most definitions highlight similar features: the number and variety of components, the relationships among them, and their potential for change over time (Blockus [41]; summarized by Harlacher *et al.* [42]). Luhmann [43] characterizes system complexity in terms of the number of elements, the diversity and quantity of their interconnections, and how these factors evolve over time.

Focusing on tasks, Wood [44] identifies three dimensions: (1) component complexity, referring to the number of distinct actions or informational inputs; (2) coordinative complexity, reflecting the relationships between task inputs and outputs; and (3) dynamic complexity, capturing the variability of inputs and their effects on outcomes. Campbell [45] similarly emphasizes information load, diversity, and change, noting that multiple solution paths and uncertainty in linking actions to results increase task complexity. Blockus [41] consolidates these perspectives into four characteristics: the quantity of subtasks, their diversity, interdependence, and changeability.

Building on these insights, we define task complexity through three attributes: (1) variety, the range of activities and information processed; (2) interdependence, the extent to which subtasks rely on each other or on environmental factors; and (3) dynamics, the unpredictability and change inherent in work processes. Variety aligns with Hackman and Oldham's [46] "skill variety" concept, reflecting the need for diverse knowledge, skills, and competencies. Interdependence includes both relationships among an individual's subtasks and connections to the broader work context, drawing on Willke's [47] system-environment perspective (cited in Blockus [41]). Dynamics encompasses uncertainty, ambiguity, and evolving task conditions, as emphasized by Klabunde [48].

Autonomy
Workplace autonomy refers to the degree of discretion and control employees have over how and when they perform their tasks. Hackman and Oldham [46] describe autonomy as the freedom to schedule work and select methods for task completion. Early research often treated autonomy as a single construct [49, 50], but contemporary studies distinguish multiple dimensions, including work method autonomy (choice of procedures) and work scheduling autonomy (control over timing and sequencing) [49-53].

Breaugh [49, 54] introduces a third dimension, criteria autonomy, reflecting an employee's ability to influence which tasks and goals are pursued, effectively determining the criteria by which performance is evaluated. This aligns with the notion of "strategic autonomy," in which individuals or teams define both problems and goals [55]. Morgeson and Humphrey [52] focus on method and scheduling autonomy, subsuming goal and task control under a broader "decision-making autonomy," which we interpret as encompassing method and scheduling autonomy rather than a separate facet.

For our study, we conceptualize autonomy as comprising three dimensions: work method, work scheduling, and criteria autonomy, while also testing decision-making autonomy to evaluate its relationship to the broader construct.

Integrating complexity, autonomy, and knowledge work
Our framework aligns with international research on knowledge work. Novelty relates to creativity and innovation (Ramirez and Steudel [56]; Reich [57], cited in Jacobs [58]; Pyöriä [30]). Complexity captures variation, interdependence, and dynamic task characteristics [56, 58-60]. Autonomy is recognized as a key component of knowledge work [30, 56, 59].

Many studies differentiate routine from non-routine work [30, 56, 59, 61, 62]. In our approach, routine/non-routine is not treated as a separate dimension but is captured indirectly through novelty, complexity, and autonomy. This approach is consistent with prior operationalizations: Davenport [60] defines routine along the complexity dimension, and Benson and

Brown [59] equate non-routine with high variation, dynamic interdependence, and autonomy. Matthes *et al.* [22] also operationalize routine versus non-routine tasks following Autor *et al.* [61], using complexity and autonomy as the core indicators.

Questionnaire development

The development of our survey instrument to measure knowledge work requirements among higher education graduates followed a four-step process. Initially, we reviewed existing German- and English-language questionnaires to identify potential indicators corresponding to the dimensions and subdimensions of knowledge work outlined above. This review produced an initial pool of 173 items, which included several items we created ourselves. From this pool, 46 items were selected for closer examination and, where necessary, translated or adapted for use **(Table 1)**.

With the exception of three items deemed unnecessary for testing, all selected items proceeded to the second stage: a cognitive pretest. This involved guided interviews with 14 graduates from a variety of academic disciplines, focusing on comprehension using mainly the probing technique. The pretest also addressed how respondents retrieved information and selected answers. Additionally, category-selection probing was used to evaluate whether the two response scales employed in the questionnaire were suitable, precise, and user-friendly. The cognitive pretesting procedures followed the methodology recommended by Prüfer and Rexroth [63].

Table 1. Number of items in the different steps of questionnaire development

Dimension	Cognitive pretest	Item collection	Development study	Final instrument
Complexity	20	72	16	9
Novelty	14	28	10	4
Autonomy	12[a]	73	13	9
Total	46[a]	173	39	22

[a] Including three items that did not need to be tested

The cognitive pretesting revealed that eight items were problematic due to misinterpretations; for example, respondents often understood “creating new knowledge” as related to teaching activities rather than work-based knowledge generation. One additional item was divided into two separate statements because it combined multiple ideas in a single prompt (“My job allows me to take initiative and exercise discretion”).

The revised set of 39 items then proceeded to the third phase, the instrument development study, with 16 items targeting complexity, 9 items measuring novelty, and 13 items addressing autonomy **(Table 2)**. Following an extensive analysis of the collected data, detailed in Section 4, 22 items were retained for the final questionnaire.

Table 2. Examples of the questionnaire items used in the instrument development study

Dimension	Subdimension	Example
Novelty		In my job I search out new solutions to problems
Complexity	Variety	The job requires me to monitor a great deal of information
	Dependency	The job activities are greatly affected by the work of other people
	Dynamics	My job requires me to respond to unforeseen situations
Autonomy	Method	The job allows me to make decisions about what methods I use to complete my work
	Scheduling	The job allows me to plan how I do my work
	Criteria	The job allows me to set my own priorities
	Decision making	The job allows me to make a lot of decisions on my own

The development study for the instrument was implemented as an online survey aimed at graduates from German higher education institutions who were already part of the HISBUS panel. HISBUS, conducted periodically by the German Centre for Higher Education Research and Science Studies (DZHW), collects data on current trends and issues in German higher education. In the winter of 2017, 652 panelists who had completed their higher education and agreed to participate in follow-up surveys were invited to take part. To encourage responses, participants were offered a lottery incentive and two reminder emails were sent. Over the course of eight and a half weeks, 580 individuals (approximately 83%) began the survey. After removing participants with extensive missing responses, those without a higher education degree, or those who were not employed after graduation, the final dataset for analysis included 411 respondents. Key demographic and background characteristics of this sample are summarized in **Table 3**.

Table 3. Sample Characteristics of the Development Study and the DZHW Graduate Panel 2009

Variable	DZHW Graduate Panel	Development Study
Gender		

Male	43%	37%
Female	57%	63%
Age (mean)	36.4[1]	29.9
Highest degree attained		
Bachelor	13%	25%
Master or equivalent[2]	66%	69%
PhD	16%	4%
Other / not specified	5%	2%
Type of higher education institution		
University	67%	63%
University of Applied Sciences	25%	33%
Other[3] / not specified	9%	4%
Occupational position		
Managerial	40%	15%
Highly qualified	31%	40%
Qualified	19%	27%
Low-skilled	1%	6%
Self-employed	6%	3%
Other / not specified	2%	8%
Total (N)	3,369	411

[1]Birth month information was not collected; age was approximated using a randomly generated uniform integer between 1 and 12.

[2]Includes diploma, magister, or state examination degrees.

[3]Includes higher education institutions outside Germany.

Sources: KWReq development study; DZHW Graduate Panel 2009, 3rd wave 2019

In addition to the core items assessing knowledge work, the questionnaire collected information on respondents' socio-demographic characteristics, educational background, and their current or most recent employment. Variables used to examine the criterion-related validity of the newly developed instrument are described in more detail in Section 4.1.

Technical issues affected 13 items measuring knowledge work requirements, resulting in a high number of missing responses. Within the analytic sample, seven variables had between 309 and 344 valid responses, while six variables had only 62 to 95 valid observations, with some pairs of variables lacking any overlapping data. Importantly, the affected items, were distributed across different dimensions and subdimensions, avoiding concentration in any single area.

The finalized instrument, consisting of 22 items across seven (sub)dimensions, was also administered in the third wave of the DZHW graduate panel survey targeting graduates from the 2009 academic year. This wave, conducted approximately ten years after graduation, was implemented as a three-part web survey. The first part, from April to June 2019, collected information on respondents' educational and occupational trajectories since the second panel wave in 2015 and on their current professional situation, achieving a response rate of 61%. The second part, conducted between August and October 2019, included the knowledge work questionnaire, which took roughly two minutes to complete.

Due to the data limitations in the KWReq development study, the DZHW graduate panel 2009 dataset was used to conduct a secondary evaluation of factorial validity and the dimensional structure of the instrument. Analyses were based on 3,369 respondents, and results are presented in Section 4.5. It is important to note that this panel sample differed markedly from the development study: participants were older, more frequently held master's or doctoral degrees, and were more often in managerial roles **(Table 3)**.

Empirical Analyses

Data analysis strategy

The analysis strategy combined exploratory and confirmatory approaches. The objectives were threefold: (1) to develop a concise questionnaire with the fewest items necessary (minimum of three per factor) while adequately capturing all dimensions and subdimensions of knowledge work in a valid and reliable manner; (2) to test the hypothesized factor structure of knowledge work, and if it did not hold, to identify a suitable dimensional model; and (3) to evaluate reliability as well as convergent, divergent, and criterion validity. The three dimensions—novelty, complexity, and autonomy—were first analyzed individually, followed by examination of the full model. Finally, the model's applicability was tested using the DZHW graduate panel data.

Construct validity and variable selection were primarily assessed using confirmatory factor analysis (CFA), supplemented by exploratory factor analysis (EFA), while scale and item reliability were calculated using Cronbach's alpha and corrected item-total correlations[2]. Structural equation modeling (SEM) was employed to evaluate criterion validity. CFA, EFA, and SEM analyses were performed in Mplus 8.4, and all other analyses in Stata 16. EFA was conducted with maximum likelihood estimation and oblique rotation, and missing data were addressed using full information maximum likelihood (FIML) estimation.

Model fit was evaluated based on several criteria: (1) RMSEA (root mean square error of approximation) measures discrepancies between observed and model-implied covariances, favoring parsimonious models. Suggested cut-offs vary: Hu and Bentler [64] propose values near 0.06; Steiger [65] allows up to 0.07; other scholars consider values below 0.08 acceptable, 0.08–0.10 mediocre but tolerable, and above 0.10 unacceptable [66, 67]. (2) The comparative fit index (CFI) evaluates improvement over the independence model. (3) The Tucker-Lewis index (TLI) is similar to the CFI but penalizes model complexity more strongly. Previously, a lower bound of 0.90 was suggested, though current standards favor values near 0.95. The chi-square test for overall model fit was reported but not used for evaluation due to its sensitivity to sample size.

Marsh *et al.* [68] caution against rigidly following these thresholds. Accordingly, we also considered other criteria, including internal consistency (Cronbach's alpha), factor loadings, and theoretical plausibility. For three-item scales, an alpha value around 0.60 was considered sufficient. Standardized factor loadings were required to be at least 0.50–0.60 to qualify as valid indicators [69].

Additional variables were included to assess divergent and criterion validity. Seven items measured research engagement: three items captured the consumption and application of research (e.g., reading scientific literature, applying research findings to processes or products; α = 0.79), while four items assessed active research involvement (e.g., conducting research, designing projects; α = 0.88).

Concurrent criterion validity was evaluated using three items capturing education-job alignment: professional position (degree-job match regarding role), task level (degree-job match regarding responsibilities), and field match (degree-job match regarding study field). Responses used a five-point Likert scale from "no match" to "good match." Additionally, participants reported the academic degree most suitable for the job (master/PhD, bachelor, none) and whether they held leadership or highly qualified positions.

The novelty dimension

The single-factor CFA model for novelty demonstrated good fit (RMSEA = 0.063; CFI = 0.976; TLI = 0.968; **Table 4**). EFA results supported this unidimensional structure, with one factor having an eigenvalue above 5, while all other factors had eigenvalues below 1.

Table 4. Novelty dimension: results of the single-factor CFA and reliability analysis

Variable	Short label	Model 1: all items		Model 2: selected items	
		Factor loading (stand.)	Item-total correlation (corr.)	Factor loading (stand.)	Item-total correlation (corr.)
n1	Creative ideas	0.78	0.74		
n2	New applications	0.78	0.74		
n3	**New solutions**	**0.81**	**0.76**	**0.82**	**0.75**
n4	**Being innovative**	**0.87**	**0.82**	**0.86**	**0.77**
n5	New products, services	0.50	0.48		
n6	**Unusual ideas, solutions**	**0.80**	**0.75**	**0.81**	**0.74**
n7	Original solutions	0.78	0.74		
n8	New ideas	0.77	0.75		
n9	**New methods, tools**	**0.80**	**0.75**	**0.79**	**0.71**
Model fit, alpha, N		$x^2(27)$ = 70.995 (p = 0.000); RMSEA = 0.063 (90% CI: (0.045, 0.081)); CFI = 0.976; TLI = 0.968; α = 0.925; N = 411		$x^2(2)$ = 4.502 (p = 0.105); RMSEA = 0.055 (90% CI: (0.000, 0.125)); CFI = 0.996; TLI = 0.988; α = 0.892; N = 409	

The items chosen for inclusion in the final instrument are highlighted in bold.
Source: KWReq development study

Relying on the strongest factor loadings and corrected item-total correlations, we retained only 4 items (n3, n4, n6, n9) for the final scale. These items cover diverse facets of the underlying construct and operate at different levels of abstraction. Item n5, which tapped the creation of new products or services, could have broadened the construct further; however, it was eliminated because of its weak loading and low correlation with the remaining items. Its very low mean score of 1.98 also suggests that this type of innovative activity is rarely demanded in the target roles.

Confirmatory factor analysis of the shortened four-item scale yielded somewhat better fit indices than the original nine-item version (RMSEA = 0.055, CFI = 0.996, TLI = 0.988), and the chi-square test was non-significant. As anticipated when the number of items is drastically reduced, Cronbach's alpha dropped from 0.925 (nine items) to 0.892 (four items). A value of almost 0.90 nevertheless signals excellent internal consistency.

The complexity dimension

The theoretically proposed structure of the complexity dimension was clearly rejected by confirmatory factor analysis (RMSEA = 0.111, CFI = 0.796, TLI = 0.757). An exploratory factor analysis conducted on the full set of complexity items indicated—according to the eigenvalue > 1 rule—a four-factor solution. Inspection of the pattern matrix, however, revealed considerable cross-loadings for the dependency items cde4 (taking possible effects on other people or areas into account) and cde5 (working independently of others) as well as the dynamics items cdy1 (keeping professional knowledge up to date) and cdy2 (regularly reviewing and adapting one's own work methods). Because of this lack of factorial clarity, these four items were removed.

A new exploratory analysis on the remaining items initially produced three factors with eigenvalues above 1. A chi-square difference test, however, demonstrated that the four-factor model fit the data significantly better than the three-factor alternative ($\Delta\chi^2 = 33.47$, $\Delta df = 9$, $p < 0.001$). We therefore opted for the four-factor solution, which achieved acceptable fit (RMSEA = 0.068, CFI = 0.975, TLI = 0.931; **Table 5**).

Table 5. Complexity Dimension: Outcomes of the Four-Factor EFA and CFA Using a Reduced Set of Variables

Variable	Short label	EFA factor loading				CFA factor loading (stand.)			
		F1	F2	F3	F4	F1	F2	F3[a]	F4
cv1	Observing a large amount of information	0.96*	0.05	0.02	− 0.01	0.82			
cv2	Handling multiple tasks simultaneously	0.28*	0.07	0.28*	0.26*	0.75			
cv3	Examining a large volume of information	0.61*	− 0.13	0.06	0.21	0.81			
Alpha subdimension "variety" = 0.84									
cde1	Relying on the efforts of others	0.11	0.72*	0.01	0.06				
cde2	A timetable contingent on others' availability	0.03	0.68*	− 0.04	− 0.14*				
cde3	Relying on the outcomes of others	− 0.07*	0.84*	0.02	0.04				
Alpha subdimension "dependency" = 0.78									
cdy3	Unexpected circumstances	− 0.08*	0.02	0.81*	0.14*			0.76	
cdy4	Immediate or impulsive responses	0.08*	− 0.02	0.93*	− 0.11*			0.77	
cdy5	Unsolvable issues	0.05	0.05	0.51*	0.28*			0.80	
Alpha subdimension "dynamics-reactive" = 0.85									
cdy6	Predicting potential issues	0.17	0.03	0.08	0.59*				0.77
cdy7	Novel or unfamiliar assignments	0.24	− 0.07	− 0.06	0.49*				0.58
cdy8	Making choices in unpredictable situations	0.01	0.09	0.10	0.62*				0.68
Alpha subdimension "dynamics-proactive" = 0.67									
Factor correlation									
	F1	1.00				1.00			
	F2	0.14	1.00			–	–		
	F3	0.56	0.18	1.00		0.81	–	1.00	
	F4	0.63	0.14	0.53	1.00	0.90	–	0.76	1.00
Model fit, N		$x^2(24)$ = 69.672 (p = 0.000); RMSEA = 0.068 (90% CI: (0.050, 0.087)); CFI = 0.975; TLI = 0.931; N = 411				= 62.697 (p = 0.000); RMSEA = 0.065 (90% CI: (0.046, 0.084)); CFI = 0.973; TLI = 0.957; N = 411			

[a] Permitting a correlation between the error terms of cdy3 and cdy4
*Significant at the 5% level
Source: KWReq development study

Table 5 reports the factor loadings obtained from the exploratory factor analysis (EFA), also referred to as the factor pattern. With oblique rotation, these loadings indicate the standardized regression coefficients of variables predicted by each factor. The results revealed a clear pattern: Factor 2 primarily influenced cde1, cde2, and cde3, with minimal association with other factors, supporting the identification of the dependency subdimension. Factor 3 displayed four significant loadings, but cv2 (0.28) had a much lower value than cdy3 (0.81), cdy4 (0.93), and cdy5 (0.51), which were largely independent of other factors, suggesting factor 3 captures reactive work behaviors within the dynamics subdimension. Factor 4 corresponded to a more proactive component of the dynamics subdimension, strongly associated with cdy6, cdy7, and cdy8, while showing negligible cross-loadings. Factor 1, representing the variety subdimension, was mainly indicated by cv1, cv2, and cv3; although cv2 had a modest loading (0.28) and some cross-loadings, its correlation with factor 1 (0.61) and high internal consistency ($\alpha = 0.84$) justified retaining it.

The factor correlation matrix indicated that factor 2 (dependency) was largely independent from the other factors ($0.14 \leq r \leq 0.18$), whereas factors 1, 3, and 4 were more interrelated ($0.53 \leq r \leq 0.63$). Based on these correlations and validity analyses, the dependency subdimension was removed, leaving the variety subdimension and the two dynamics subdimensions (reactive and proactive) as the retained structure. External criteria, including education-job match and leadership positions, correlated with the retained factors but not with dependency, further supporting this decision.

Confirmatory factor analysis of the reduced model showed acceptable fit (RMSEA = 0.065; CFI = 0.973; TLI = 0.957) with factor loadings ranging from 0.58 to 0.82. The residuals of cdy3 and cdy4 were allowed to correlate due to modification indices, reflecting shared variance likely caused by both items containing the German verb reagieren. Despite acceptable fit, the “dynamics-proactive” subdimension was measured less effectively compared to other factors.

Autonomy dimension

Autonomy was conceptualized as comprising three subdimensions: work scheduling, work methods, and criteria autonomy. Confirmatory factor analysis supported this structure **(Table 6)**, showing good overall fit (RMSEA = 0.059; CFI = 0.975; TLI = 0.963), strong factor loadings ($0.63 \leq \lambda \leq 0.86$), and adequate internal consistency ($0.75 \leq \alpha \leq 0.88$). Among the three, the criteria subscale demonstrated weaker measurement quality than the work scheduling and method subdimensions, the latter of which relied on validated instruments developed by Morgeson and Humphrey [52] and translated into German by Stegmann *et al.* [70].

Table 6. Autonomy dimension: results of the three-factor CFA model (stand. factor loadings)

Variable	Short label	Method	Scheduling	Criteria
am1	Freedom in how to do the work	0.83		
am2	Deciding on approaches	0.70		
am3	Deciding on methods	0.85		
as1	Deciding on the order		0.78	
as2	Decision about scheduling the work		0.82	
as3	Freedom to plan how to do the work		0.86	
ac1	Modifying the job objectives			0.69
ac2	Influencing the workload			0.63
ac3	Setting own priorities			0.84
	Alpha	0.83	0.88	0.75
	Factor correlation			
	Method	1.00		
	Scheduling	0.81	1.00	
	Criteria	0.87	0.84	1.00
	Model fit, N	$x^2(24)$= 58.173 (p = 0.000); RMSEA = 0.059 (90% CI: (0.040, 0.078)); CFI = 0.975; TLI = 0.963; N = 411		

Source: KWReq development study

Morgeson and Humphrey [52] proposed that decision-making autonomy represents an additional dimension of autonomy. Following Breaugh [49] and treating decision making as an overarching construct with multiple subcomponents, we chose to concentrate on the more precise aspect of criteria autonomy. To explore the structure of the decision-making factor, we estimated an additional measurement model that incorporated decision-making items and specified a second-order factor encompassing method, scheduling, and criteria autonomy. The findings partially confirmed our expectations: the four first-order factor CFA revealed that decision making and method autonomy were almost identical (correlation = 0.97), suggesting they largely capture the same construct, while correlations of decision making with scheduling autonomy and criteria autonomy were lower (0.71 and 0.83, respectively). Based on this, we retained method autonomy, given its greater specificity, which was further supported by a 0.94 correlation between decision making and the second-order factor representing method, scheduling, and criteria autonomy.

Complete model

A first-order CFA was first conducted including the novelty dimension, the complexity dimension (with subdimensions of variety, dynamics-reactive, and dynamics-proactive), and the autonomy dimension (subdivided into method, scheduling, and criteria autonomy). The model demonstrated satisfactory fit (RMSEA = 0.056, CFI = 0.941, TLI = 0.927). A subsequent second-order CFA, introducing higher-order factors for complexity and autonomy, showed reduced fit (RMSEA = 0.063, CFI = 0.922, TLI = 0.910) along with increased AIC and BIC values. Consequently, the first-order model was retained as the preferred representation. Results are summarized in **Figure 1**.

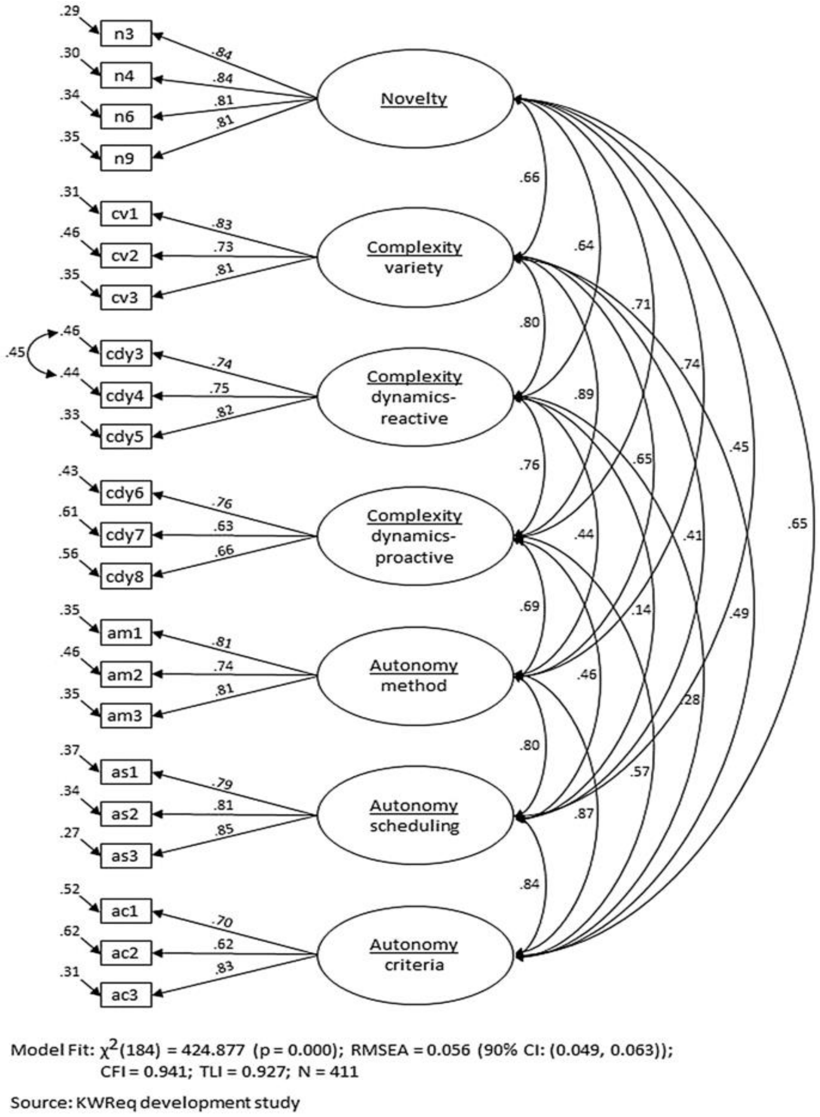

Figure 1. Full CFA model of the KWReq questionnaire (standardized factor loadings)

Although the CFI and TLI values did not reach the conventional threshold of 0.95, the overall model fit is deemed acceptable. Specifically, the RMSEA was below 0.06, and even the upper limit of its confidence interval slightly exceeded 0.06. All factor loadings were statistically significant and above 0.60, ranging from 0.62 to 0.85. Furthermore, the correlations among latent factors support the proposed dimensional structure of the "knowledge work" construct: correlations among factors within the same dimension (e.g., complexity or autonomy) were consistently higher than correlations between factors from different dimensions (complexity, autonomy, and novelty).

Table 7 highlights this pattern more clearly, presenting latent factor correlations derived from a CFA conducted to evaluate the divergent validity of the knowledge work questionnaire, incorporating the two research dimensions described in Sect. 4.1. Although this CFA differs from the original, "pure" knowledge work model, the inter-factor correlations remain largely consistent. Additionally, **Table 7** demonstrates that the two research-related factors represent a separate construct: while these research factors correlate at 0.68 with each other, their correlations with the knowledge work dimensions are substantially lower, indicating distinctiveness between research involvement and knowledge work factors.

Table 7. Full CFA model with research dimensions: correlations among latent factors

Dimension	Subdimension	Novelty	Complexity Variety	Complexity Dynamics-reactive	Complexity Dynamics-proactive,	Autonomy Method	Autonomy Scheduling	Autonomy Criteria	Research consumption	Research active
Novelty	–	1.00								
Complexity	Var	0.66	1.00							
	Dyn.-react	0.63	0.80	1.00						
	Dyn.-proact	0.71	0.90	0.76	1.00					
Autonomy	Meth	0.74	0.65	0.44	0.70	1.00				
	Sched	0.45	0.41	0.14	0.48	0.80	1.00			
	Crit	0.65	0.49	0.28	0.58	0.87	0.84	1.00		
Research	Res. cons	0.51	0.39	0.29	0.53	0.52	0.36	0.46	1.00	
	Res. act	0.33	0.10	0.08	0.25	0.29	0.28	0.37	0.68	1.00

Model fit indices: $\chi^2(337) = 767.551$, $p = 0.000$; RMSEA = 0.056 (90% CI: 0.051–0.061); CFI = 0.925; TLI = 0.911; N = 411

Source: KWReq development study

Finally, we assessed concurrent criterion validity using structural equation modeling, conducting separate analyses in which each knowledge work factor was regressed individually on the external variables outlined in Sect. 4.1, treating the independent variables as manifest, with the unstandardized regression coefficients and the corresponding explained variances (R^2) summarized in **Table 8**.

Table 8. Associations between the knowledge work factors and external criteria (separate SEM models for each criterion)

External criterion	Novelty	Complexity			Autonomy		
		Var	Dyn.-react	Dyn.-proact	Meth	Sched	Crit
Regression coefficients (unstandardised)							
Education-job match regarding							
…The professional position	0.22***	0.19***	0.07**	0.25***	0.28***	0.21***	0.24***
… Level of task	0.29***	0.24***	0.13***	0.32***	0.34***	0.23***	0.27***
…The professional qualification	0.26***	0.19***	0.11***	0.26***	0.28***	0.20***	0.22***
Most appropriate academic degree (ref. cat.: no degree)							
Bachelor's degree	0.84***	0.76***	0.51***	0.73***	0.88***	0.62***	0.60***
Master's degree[a] or PhD	0.92***	0.82***	0.39***	1.05***	0.91***	0.74***	0.70***
Leadership or highly qualified position (yes vs. no)	0.50***	0.44***	0.23**	0.58***	0.41***	0.36***	0.28**
Explained variance (R^2)							
Education-job match regarding							
…the professional position	0.12***	0.14***	0.02	0.24***	0.20***	0.13***	0.16***
… Level of task	0.21***	0.21***	0.07*	0.34***	0.26***	0.14***	0.19***
…Professional qualification	0.17***	0.12**	0.04	0.22***	0.18***	0.11**	0.13***
Highest relevant academic degree	0.16***	0.18***	0.06*	0.30***	0.15***	0.11**	0.10**
Leadership or senior/expert position (yes vs. no)	0.08**	0.08**	0.03	0.14***	0.05*	0.04	0.03

Variety (Var), Dynamics-reactive (Dyn.-react), Dynamics-proactive (Dyn.-proact), Method (Meth), Scheduling (Sched), Criteria (Crit), Research consumption (Res. cons), Research active (Res. act)

*$p < 0.05$, **$p < 0.01$, ***$p < 0.001$

[a] Or equivalent

Source: KWReq development study

All regression coefficients were statistically significant, yet the proportion of variance explained was limited. The independent job-related variables accounted for a meaningful share of variance only in the proactive dynamics dimension, with R^2 values ranging from 0.14 to 0.34, and a full SEM model including all predictors yielded $R^2 = 0.43$ (not shown). This indicates that the proactive dynamics factor effectively differentiates higher education graduates with varying job characteristics. In contrast, these variables explained very little of the variance in reactive dynamics ($0.02 \leq R^2 \leq 0.07$; full model $R^2 = 0.11$), suggesting that reactive dynamics are relatively independent of other job features. Mean scores for this factor show that reactive dynamics are prevalent among graduates but display little variability, resembling the variety dimension in this regard.

Among the external predictors of the knowledge work dimensions, the alignment between education and task level emerged as the most influential, showing the highest R^2 across all dimensions. The next most relevant factor varied by dimension: for autonomy, the education-job match concerning professional position was the second strongest predictor, while for complexity, the suitability of the academic degree for the role was the second most important. Overall, these results indicate adequate criterion validity.

The KWReq questionnaire was subsequently tested with the DZHW graduate panel. Differences in highest academic degree and a ten-year gap between graduation and the third panel wave meant that the 2009 cohort had more advanced careers than the original development sample **(Table 3)**, and they generally rated knowledge work items higher. The exception was the dynamics-reactive dimension, which showed similar or slightly lower means. Nevertheless, the dimensional structure of the instrument remained consistent with the development study.

CFA results indicated acceptable fit (RMSEA = 0.056; CFI = 0.944; TLI = 0.931; **Table 5**), with all factor loadings significant and in the range 0.60–0.89. Internal consistency (Cronbach's alpha) was satisfactory to good, although often slightly lower than in the development sample. Correlations between latent factors were weaker than in the original study but followed a similar pattern: within-dimension correlations were stronger than between-dimension correlations, except for a lower correlation between proactive dynamics and variety (0.66) compared to proactive dynamics and novelty (0.74).

The motivation for this study was the lack of instruments capable of capturing knowledge work among highly qualified employees and the need for higher education institutions to respond to labor market changes. The resulting 22-item questionnaire primarily addresses job activities and partially captures job characteristics, highlighting knowledge work as a central aspect of the modern economy. It can be administered online or via other survey modes, as demonstrated in PIAAC and NEPS studies, and is short enough for multi-topic surveys. It successfully differentiates among groups of higher education graduates and provides reliable and valid measurement of three theoretically derived knowledge work dimensions: novelty, complexity, and autonomy.

Novelty was operationalized in terms of innovative work. Complexity was initially conceptualized as comprising variety, dependency, and dynamics, while autonomy included scheduling, methods, and criteria (strategic) autonomy. Analyses, however, did not support dependency as a valid subdimension of complexity and revealed two forms of dynamic complexity: reactive dynamics, reflecting ad hoc responses, and proactive dynamics, reflecting active management of uncertainty and unpredictability. Proactive dynamics explained a substantial portion of variance in occupational position and education-job match, whereas reactive dynamics showed weak associations, indicating that proactive dynamics is a stronger indicator of knowledge work.

The failure of dependency to emerge as a valid component may reflect its operationalization. Dependency generally refers to interdependence among tasks or with the environment, but the measure used here focused on "received interdependence," or how much one's work is affected by others' tasks [52]. Two of the three items were adapted from the WDQ "received interdependence" subscale [70], and the third was informed by the same questionnaire. Since this form of dependency is also common in routine work, it may not align with other aspects of complexity or knowledge work. Future studies should explore more suitable ways to measure dependency and determine which forms are essential to knowledge work.

Another limitation concerns the novelty dimension. While innovative work is central, a reflective measurement model may be suboptimal, as reflective indicators are assumed to correlate strongly and be interchangeable manifestations of the latent construct. Formative models, in contrast, allow indicators to capture different facets without high correlation, with causality running from indicators to the latent factor. The item "In my job I develop new products or services" (n5, **Table 9**) showed weak correlations with other novelty items and was therefore excluded, although it remains a strong indicator of innovation. A formative approach, analyzed with methods such as PLS-SEM [71, 72], may be better suited to capturing this knowledge work dimension.

Table 9. Full CFA model of the KWReq questionnaire applied to the DZHW graduate panel 2009 (stand. factor loadings)

Item	Novelty	Complexity			Autonomy		
		Variety	Dynamics-reactive[a]	Dynamics-proactive	Method	Scheduling	Criteria
n3	0.77						
n4	0.82						
n6	0.80						
n9	0.67						
cv1		0.81					
cv2		0.71					
cv3		0.82					
cdy3			0.68				
cdy4			0.70				
cdy5			0.75				
cdy6				0.62			

cdy7				0.60			
cdy8				0.73			
am1					0.80		
am2					0.82		
am3					0.81		
as1						0.74	
as2						0.85	
as3						0.89	
ac1							0.73
ac2							0.71
ac3							0.82
Alpha	0.85	0.82	0.79	0.68	0.85	0.86	0.79
Factor correlations							
Novelty	1.00						
Variety	0.48	1.00					
Dyn.-reactive	0.50	0.58	1.00				
Dyn.-proactive	0.74	0.66	0.75	1.00			
Method	0.55	0.24	0.23	0.34	1.00		
Scheduling	0.23	0.04	− 0.10	0.08	0.53	1.00	
Criteria	0.46	0.14	0.07	0.23	0.71	0.64	1.00
Model fit, N	x^2(187)= 2181.035 (p = 0.000); RMSEA = 0.056 (90% CI: (0.054, 0.058)); CFI = 0.944; TLI = 0.931; N = 3369						

[a]Allowing a correlation between the error terms of cdy3 and cdy4
Source: DZHW graduate panel 2009, 3rd wave 2019

Future work involves creating a rigorously validated English version of the questionnaire and exploring options for reducing its length. While an English version already exists—combining original English items with translations from German—these translations have yet to be verified through backward translation or other quality assurance methods. Moreover, cognitive testing and standardized empirical evaluations are still needed. Regarding instrument length, the study's findings suggest possible ways to streamline the questionnaire; although we do not advise cutting items within individual (sub)dimensions, it may be worth considering the removal of an entire factor if simplification is necessary.

Despite these unresolved issues, the current version of the questionnaire is ready for empirical research on the knowledge work demands of higher education graduates. Initial concerns about data reliability and technical difficulties in the development study were mitigated when the results were confirmed in a representative survey of graduates at later career stages. The instrument provides a foundation for examining questions such as differentiating types of knowledge work from a person-centered perspective, investigating how knowledge work varies across the highly qualified workforce, tracking changes in knowledge work frequency and intensity over time, and assessing how job requirements evolve throughout an individual's career. Insights from such studies can inform understanding of the link between higher education and employment outcomes and may support curriculum development initiatives.

However, the instrument has limitations: because it only captures data from graduates, it is less suited for evaluating the overall supply and distribution of graduate-level jobs—roles in which the primary skills are typically acquired through higher education.

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