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Perspectives of digital competencies. A comparison of different constructs of digital pedagogical competencies

Abstract

Digital pedagogical competency is a core competency for teachers, yet its definition and assessment methods lack consensus. Authors using different theories and methodologies reach similar conclusions, prompting exploration of overlaps in conceptualizations. Based on the DPaCK-model, three subareas of 'digital pedagogical competencies' were examined through a merged version of three instruments, assessing their independence and distinct facets. A total of N = 484 students from Germany took part in the survey. Confirmatory factor analysis revealed high intercorrelations and inconclusive results. Exploratory factor analysis suggested a three-factor structure: (1) general digital competence, (2) learning and teaching-related digital competence, and (3) precautions regarding digital technology. Comprehensive assessment of digital competences needs to take into account that we are dealing with a composite construct.

Keywords

digital competency, teacher professionalism, assessment of digital competencies, digital teacher education

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Perspektiven digitaler Kompetenzen. Ein Vergleich verschiedener Konstrukte digitaler pädagogischer Kompetenzen

Zusammenfassung

Digitale pädagogische Kompetenz ist eine Kernkompetenz, die für Lehrkräfte unverzichtbar ist, über deren Definition und Bewertungsmethoden jedoch kein Konsens besteht. Autor:innengruppen, die verschiedene Theorien und Methoden verwenden, kommen zu ähnlichen Schlussfolgerungen, was die Untersuchung von Überschneidungen in den Konzeptualisierungen veranlasst. Drei Teilbereiche digitaler pädagogischer Kompetenzen wurden mithilfe von drei Instrumenten untersucht, die die Unabhängigkeit und unterschiedliche Facetten bewerten. Insgesamt nahmen N = 484 Studierende aus Deutschland an der Umfrage teil und testeten die Unabhängigkeit der Konstrukte. Die konfirmatorische Faktorenanalyse ergab hohe Interkorrelationen und uneindeutige Ergebnisse. Mittels explorativer Faktorenanalyse wurde folgende drei-faktorielle Struktur angegeben: (1) allgemeine digitale Kompetenz, (2) lern- und lehrbezogene digitale Kompetenz und (3) Vorsichtsmaßnahmen im Umgang mit digitaler Technologie. Bei einer umfassenden Bewertung der digitalen Kompetenzen muss berücksichtigt werden, dass es sich um ein zusammengesetztes Konstrukt handelt.

Schlüsselwörter

digitale Kompetenzen, Lehrerprofessionalität, Messung von digitalen Kompetenzen, digitale Lehrerausbildung

1 Introduction

The assessment of digital competences in teacher training continues to be a challenge with inconclusive answers. In addition to being indispensable for (prospective) teachers, there is general agreement that digital competencies comprise skills pertaining to the use of digital devices for both learning and teaching, and that teacher education programs are accountable for providing opportunities for adequate skill development. However, the assessment of digital competencies in teacher training continues to be a challenge. The issue of valid assessment instruments both to determine the point of departure and to demonstrate the progress that students make related to digital competencies must still be resolved. A variety of instruments for the assessment of digital competences in the form of self-report questionnaires have been proposed. However, the instruments that claim to measure digital competences use quite different conceptualizations of the construct. The aim of the current study is to compare and analyze three existing instruments in terms of construct definition, scale composition, and diagnostic potential. Core competencies of the teaching profession, summarized in the DPaCK model, which is comprised of three inter-related sub-areas: content competency, pedagogical competency, and digital competency (Huwer et al., 2019).

Content competency includes the subject-related knowledge and didactic strategies needed to teach a subject or topic. Pedagogical competency integrates knowledge and skills related to planning, instructing, and reflecting lessons that are effective for learning. Digital competency allows a person to recognize, describe, reflect, and shape digital material and content and to use it purposefully to achieve personal goals. Skill development in these areas of digital competency, as well as a sense of confidence in teaching with digital media, should be initiated in early phases of teacher education, so that students acquire a healthy self-efficacy for being a teacher (Petko, 2012).

This paper sets out to examine three existing constructs that could be used to measure individual differences in the area of digital pedagogical competency, as defined in the DPaCK model. First, we will discuss the definition of the construct of digital

teacher competencies and pertaining implications for assessment, and then to empirically investigate their conceptual overlap and differences.

2 Theoretical Background

2.1 Competencies in the Teaching Profession

Educational research on teachers and teaching has brought forward comprehensive models to capture competencies of teachers (e.g., Helmke & Weinert, 2009; König & Blömeke, 2009; Baumert & Kunter, 2006; Seifried & Wuttke, 2016). These models typically include professional knowledge, teaching quality, self-regulation competences, and beliefs and career motivation.

Research suggests that (digital) professional competencies are more than an accumulation of skills and that interrelations need to be considered (Fischer & Kauertz, 2020; Huwer et al., 2019). Connections exist between (1) a sense of confidence and self-efficacy when using digital media in the classroom, (2) competences related to using digital media, and (3) the use of digital media and one's self-assessment of actual competences related to using digital devices and creating digital content purposefully for learning and teaching (Benz & Ludwig, 2023; Petko, 2012).

2.2 Concepts of Digital Competency in the Teaching Profession

Three different author groups (Doll & Meyer, 2021; Hughes, 2013; Rubach & Lazarides, 2019) define their research under the umbrella topic of assessment of digital competency, and use benchmarks to assess teachers within this domain. Against the backdrop of Petko (2012), their work can be categorised into three domains. The SWIT questionnaire developed by Doll and Meyer (2021) could be assigned to the sense of confidence when teaching digital competencies in the classroom (sub-area

1). Hughes' (2013) questionnaire would be subject to the general digital competencies of teachers (sub-area 2), while competence assessment (sub-area 3) follows the self-assessment questionnaire by Rubach and Lazarides (2019).

Though all instruments use identical terms for their constructs, the actual survey questions differ in terms of interpretations and conceptualizations of these shared labels. The heterogenous definitions imply that digital competence is probably not a one-dimensional construct, and that various facets are addressed and integrated under that heading.

Taking a closer look at the three constructs proposed by the different author teams, marked distinctions can be detected. Two of the three author groups suggest that digital competences be evaluated in the context of self-efficacy expectancy (Doll & Meyer, 2021; Hughes, 2013). Self-efficacy plays a special role in teaching profession. Future teachers must not only be self-efficacious, but must promote and support the thoughts and approaches of self-efficacy in pedagogical aspects of their work. However, self-efficacy can be interpreted in different areas of competency domains. For example, one aspect of self-efficacy is based on general digital technology self-efficacy (Hughes, 2013), while another lies in the integration of digital technologies into the classroom (Doll & Meyer, 2021).

This paper aims to compare the measurements of self-assessment of digital technology by Doll and Meyer (2021), Hughes (2013), and Rubach and Lazarides (2019), even if they do not use the same constructs. For initial and continuing teacher education, this would allow for a more focused area of research. The three measurement instruments are compared in Table 1 (see Appendix) to clarify overlap, intersections, as well as differences.

2.3 Research question and hypotheses

This study aims to examine three different constructs under the umbrella topic of digital competency and to examine whether they represent different sub-areas: general digital competence, perception of competence and sense of confidence to teach

digital technologies in the future (Doll & Meyer, 2021; Hughes, 2013; Rubach & Lazarides, 2019). The question is if the three constructs for the assessment of competency in the context of digital technology are distinct.

To address this research question, the present study investigates the relationship between three different constructs of digital pedagogical competence. Building upon the theoretical assumptions and previous empirical findings as outlined above, the hypotheses identify certain competences of students and allow a mapping of the current situation of student teachers in terms of digital competences. We hypothesize that the measures of Doll and Meyer (2021), Hughes (2013), and Rubach and Lazarides (2019) are independent and thus measure different subdomains of digital competences.

In case that the constructs are not independent but interdependent, an exploratory approach will be used to investigate whether it is possible to combine the factors and, thus, merge the measurements into one. By means of an explorative factor analysis, we will investigate which associations can be found between the three measurement instruments and which structure emerges in the survey of digital competency.

3 Method

3.1 Participants

A total of N = 484 students enrolled in university teacher training programs at various universities and colleges in Germany took part in the survey. As missing values are often a methodological challenge in educational research, and as missing values can lead to biased results or a smaller usable sample size, the dataset was cleaned to exclude all records below a 75 % completion rate from the analyses. This was necessary as the questionnaire was not presented in a randomized, but in a fixed order. After adjustment of the data set, the total number of participants was narrowed down to $n = 329$.

Of students surveyed, 94.1 % were training to teach at a high school level, 1.5 % for middle school, and 0.4 % for primary school. A total of 224 students were enrolled in a Bachelor's degree program at the time of the survey, 133 students in a Master's degree program, and 14 in the state examination program. In the sample, 67.5 % of the respondents identified themselves as female. The survey was distributed to universities and colleges with a teacher training program across Germany.

Two bouts of data collection took place during the regular semester periods: one over a six-week period between April and August 2022, and the second from May to June 2023. Data was collected via an online, self-paced survey tool (LimeSurvey). The survey comprehended a total of 74 items, and completion time was approximately 15 minutes. Students were invited to participate via flyers, personal outreach, and social media. The questionnaire had been partially answered by 37.4 % of the participants. Thus, response rate was overall satisfactory. The anonymity of the responses and of the respondents was always secured. The students were informed about the aim of the data collection. Participation was voluntary with written consent to participate and without gratification.

3.2 Procedures

Data analysis was performed in several steps. First, statistical software *R* with the integrated package *psych* was used for descriptive data, *ltm*, *lavaan* and *stats* for correlations and regression analyses.

3.3 Measures

Via multi-measure analysis we considered three instruments, looking at assessment of digital technology at student teachers.

Digital technology self-efficacy (DTSE). Hughes and colleagues (2013) adapted Holcomb's (2004) 17-item questionnaire for self-efficacy in using computers and digital technologies. Twelve out of 17 items of DTSE are, without further information from the authors, inverted. A German version of this questionnaire was used.

Self-efficacy of teachers regarding the integration of digital technologies in the classroom (SWIT). We used Doll and Meyer's questionnaire (2021) to survey teachers' self-efficacy regarding instructional integration of digital technology (SWIT), with a focus on digital teaching.

A digital literacy self-assessment scale for student teachers (SKL). For a broad measure of digital competences, we used Rubach and Lazarides' (2019) measurement for digital literacy for student teachers. This instrument is based on the European frame of reference for digital competence.

Items appeared in coherent blocks. Items were rated on a scale from 1 (strongly disagree) to 5 (strongly agree). Internal consistency was calculated as Cronbach's α and ranged between .87 and .95 (see Table 2).

Table 2: *n*, sample items and Cronbach's Alpha of chosen questionnaires

	Sample items*	*n*	Items	α
DTSE	"I consider myself a talented digital technology user."	268	17	.87
SWIT	"How confident are you that you can use digital media effectively?"	301	10	.88
SKL	"I can share information, files and links."	299	23	.95

Note. DTSE = digital technology self-efficacy. SWIT = Self-efficacy of teachers regarding the integration of digital technologies in the classroom. SKL = A digital literacy self-assessment scale for student teachers.

4 Results

4.1 Planning statistical analyses

To test the core hypothesis, a confirmatory factor analysis was run to check whether the respective three constructs load on three different factors (Hu & Bentler, 1999; Moosbrugger & Kelava, 2012). For the present paper, this means that the items within the instruments should correlate as strongly as possible with each other and as low, as possible with the items of the other two constructs. The correlation matrix was inspected. Confirmatory factor analysis was run to test whether the underlying items reflected their construct as a factor.

4.2 Descriptive Statistics

Table 3 displays the descriptive statistics for the three instruments. Participants' assessments of digital literacy were on average in a high range and with similar variance. Rubach and Lazarides' (2019) instrument had the highest scores. The digital technology self-efficacy (Hughes, 2013) and the scale of Doll and Meyer (2021) were close.

Table 3: Descriptive statistics: Number of valid cases, mean values, and standard deviation of the examined variables.

Variables	*n*	*M*	*SD*
DTSE	283	3.42	.7
SWIT	309	3.45	.8
SKL	329	3.72	.7

4.3 Confirmatory factor analysis

The aim of the study was to identify whether three different subconstructs could be observed. The analysis revealed that the data were not normally distributed. Since there are missing values in the data, a robust estimator was used to prepare the data in an interpretable way (MLR). It was examined whether the three factors were independent of each other. The results of the confirmatory factor analysis showed inconsistent results.

As recommended by Hu and Bentler (1999), we looked at the RMSEA and one other fit indicator. Although the results of the tested model indicated a moderate model fit (*RMSEA* = .067, *SRMR* = .065, *p*-value = < .001), other indices indicated that for the scores the analyzed model did not fit (*CFI* = .78, *TLI* = .77).

Even if the hypothesis can be partially accepted, the factor structure should be checked using an explorative approach. The correlations between the constructs DTSE and SWIT (r = .56, p-value = < .001), DTSE and SKL (r = .55,°p-value°=°<°.001) and SWIT and SKL (r = .43, p-value = < .001) showed moderate to high correlations.

Figure 2 shows in detail the factor loadings that loaded particularly highly on the individual factors. It also shows the correlations of the three constructs (see Appendix). The moderate to high correlations show a high degree of dependency between the constructs. To further investigate the factor structure, an exploratory factor analysis was carried out in the next step.

4.4 Exploratory factor analysis

We used an exploratory factor analysis to check which factor structure would be present when all items from all three questionnaires were collapsed. To check whether the items are suitable for EFA at all, the Kaiser-Mayer-Olkin criterion (*KMO*) was applied. The results revealed a marvelous sampling (*KMO* = .93). Using the Bartletts test, it was examined whether the items were sufficiently interrelated so that an exploratory factor analysis could be performed. The Bartlett test showed good

fit with $p = .009$. A Promax-rotation was performed to interpret the results. The parallel analysis recommended a structure with three factors. The results of the analysis revealed that some items should be assigned to two of the three factors. After a cutoff at .5 for good or very good fit, items under the cutoff-criterion were excluded.

The three factors were returned quite clearly (Figure 3). By means of the Fürntratt-Criterium, items with double loadings and low fit were excluded. While the first factor (only items from SKL) showed the general digital competences. The items from SWIT and SKL questionnaires were mixed in the second factor of teaching and learning-related digital competences. The third factor was made up exclusively by items from DTSE: Precautions regarding digital technology. All three factors returned high reliability. The EFA results clearly showed three sub facets, but these were not reflective of the structure that had been inherent in the original instruments.

Table 4: Reliability of the three factors found through EFA.

Factor	Name of factor	Sample items	α
Factor 1	General digital competence	I recognize the potential of using digital media for teaching content.	.93
Factor 2	Learning and teaching-related digital competences	I can evaluate tools for learning opportunities and use them independently.	.78
Factor 3	Precautions regarding digital technology	Sometimes I find working with digital technologies very confusing.	.85

Note. $n = 329$.

5 Discussion and Future Perspective

5.1 The present study

The aim of this paper was to clarify instruments which claim to measure the same construct of digital pedagogical competence and if they cover different facets of the same topic. The instruments analyzed were Hughes measurement of digital technology self-efficacy (2013 self-efficacy of teachers regarding the integration of digital technologies in the classroom (Doll & Meyer, 2021); and a self-assessment scale for student teachers of digital literacy (Rubach & Lazarides, 2019). The present paper examines whether the measurements represent different variations of the same subject. All items from the three questionnaires were collapsed into one measurement, producing a total of 69 items to investigate the structure of the instruments.

Confirmatory factor analysis did not find clear evidence for the assumption that the constructs are independent of each other. The confirmatory approach raised questions, as the fit indices were not entirely in favor of a three-factorial model.

One obstacle could be that the constructs reveal different sub-constructs that did not receive attention here. An exploratory factor analysis provided sufficient clarity in this regard. The factor loadings revealed that 27 items covered the construct in a satisfactory manner. The pattern of results can be taken as evidence for three subareas, namely: 1) general digital competence, 2) learning and teaching-related digital competence, and 3) precautions regarding digital technology. A striking feature of the exploratory approach is that seven of eight items are inverted in Factor 3. Thus, the question remains open whether this is a permanent aspect, even though the items were reversed. For Factor 2, we found that the two instruments of Doll and Meyer (2021), and Rubach and Lazarides (2019) contribute equally to the factor. The constructs taken together in the questionnaire appear to show a large overlap in digital teaching. An important question is how these areas can be sufficiently promoted and practiced, so that future teachers are well prepared for the classroom.

5.2 Practical Implications

Looking back at the literature, we wanted to compare three measurements regarding digital pedagogical competence. The measurements used correlated moderatly with each other and thus could be included in the same place in the section of the DPaCK model, as well as integrate the digital and pedagogical competences of student teachers. Correlations show a moderate connection. Due to the blending of the constructs of SWIT and SKL, it can be assumed that both constructs tap into a similar set of competencies. The distinction seems to be that SWIT is more suitable for querying the beliefs of prospective teachers, while the more-detailed SKL covers the competence areas of a specific digital model (DigComp). Even though SWIT is the most current instrument for measuring digital competencies of student teachers, the SKL instrument by Rubach and Lazarides (2019) captures more specific facets of competencies.

Results of the exploratory factor analysis demonstrate that three different sub-facets are present. The factors can be divided in terms of content into general digital competences, teaching and learning related competences, and the fear of failure regarding digital competences. Even though the analysis has not yet been validated, the recommendation is that only the items of the second factor area (learning and teaching-related digital competences) need to be considered when surveying teachers' digital pedagogical competencies. For diagnostic purposes, it remains relevant to use multiple questionnaires to reveal different facets of digital pedagogical competence. The present work suggests that the short scale might be sufficient to capture the three facets of digital pedagogical competence. Through the present work it was demonstrated that the instrument self-efficacy of teachers regarding the integration of digital technologies in the classroom does not map much added value. For teachers, it is not only important to know their own competences, but also to be able to pass them on and to recognize and evaluate the competency areas of their students. The idea of the present study was to create a more standardized self-assessment of digital competences for (prospective) teachers.

5.3 Limitations and future directions

This study had several limitations. First, factor analyses are often used in exploratory studies. The preset confirmatory factor analysis used in this study was based on the literature, and could be excluded based on these presumed structures. The parallel analysis additionally provides clues to the correct interpretation. The present study was based on a problem definition that is in the field of pedagogical-psychological research. Digital competences occupy a large area in everyday life, as well as in school and teaching, and the assessment of one's own competences is highly relevant. To gain an overview and to be able to use the correct measuring instruments, the comparison of the constructs presented here was carried out. After the exploratory approach to clarify the factor structure, it would be of interest to validate it in a next step and to test whether novices differ in their assessments from experienced teachers.

The topic of digital competences in teacher training is considerable and very relevant. This is particularly the case for future teachers, who not only have to apply their own competences themselves, but also teach them. This raises questions as to how students assess their own abilities and whether they are prepared for teaching with and for digital competences. The problem that may arise here is an overestimation of one's own competencies in order to appear more capable than they actually are. Finally, Hughes' questionnaire (2013) contains a number of inverted items. The difference in wording compared to other questionnaires may have been the reason for a separate factor in the EFA.

The omission of third variables raises the risk that student teachers' digital competence is related to their affinity for or fear of digital technologies. Second, the questionnaire was also quite long. This can help explain the high drop-out rate, but also suggests that concentration may have waned during completion. Additionally, Hughes' questionnaire (2013) contains many inverted items; due to different wording, this may have contributed to the discovery of a separate factor in the EFA. The

development of the DPaCK model is very current. This creates finer and more detailed descriptions of the different sub-facets of the model. Further studies regarding digital competencies are expected.

5.4 Conclusion

This study contributes to the understanding of different theories and definitions of digital pedagogical competence. Based on the results of the factor analyses, we suggest that different measurements of digital pedagogical competence for student teachers need to be combined to account for the relevant facets of digital pedagogical competence. The results of the current study provide evidence for the multi-structural nature of digital pedagogical competence of (student) teachers, and specify general digital competence, learning and teaching-related digital competence, and precautions regarding digital technology, as relevant facets.

6 References

Baumert, J., & Kunter, M. (2006). Keyword: Professional competence of teachers. *Journal of Educational Science, 9*(4), 469–520. https://doi.org/10.1007/s11618-006-0165-2

Benz, G., & Ludwig, T. (2023). Going beyond general competencies in teachers' technological knowledge: Describing and assessing pre-service physics teachers' competencies regarding the use of digital data acquisition systems and their relation to general technological knowledge. *Frontiers in Education*. https://doi.org/10.3389/feduc.2023.1180973

Doll, J., & Meyer, D. (2021). *SWIT – Self-efficacy of teachers with regard to instructional integration of digital technology*. Leibniz Institute of Psychology (ZPID). https://doi.org/https://doi.org/10.23668/psycharchives.4872

Fischer, H. E., & Kauertz, A. (2020). Competencies and requirements for teachers. In E. Kircher, R. Girwidz, & H. Fischer (Eds.), *Physics didactics: methods and contents* (pp. 97–126). Springer Spektrum. https://doi.org/10.1007/978-3-662-59496-4

Helmke, A., & Weinert, F. E. (2009). *Teaching quality and teachers' professionalism. Diagnosis, evaluation, and* improvement of teaching. Kallmeyer.

Holcomb, L. B., King, F. B., & Brown, S. W. (2004). Student traits and attributes contributing to success in online courses: Evaluation of university online courses. *Journal of Interactive Online Learning*, *2*(3), 1–17. https://www.learntechlib.org/p/161511

Hu, L., & Bentler, P. (1999). Cutoff criteria for fit indexes in covariance structure analysis: Conventional criteria versus new alternatives. *Structural Equation Modeling, 6*(1), 1–55. https://doi.org/10.1080/10705519909540118

Hughes, J. (2013). Descriptive indicators of future teachers' technology integration in the PK-12 classroom: Trends from a laptop-infused teacher education program. *Journal of Educational Computing Research*, *48*(4), 491–516. https://doi.org/10.2190/EC.48.4.e

Huwer, J., Irion, T., Kuntze, S., Schaal, S., & Thyssen, C. (2019). From TPaCK to DPaCK – Digitization in the classroom requires more than technical knowledge. *Mathematical Science Education, 72*(5), 358–364.

König, J., & Blömeke, S. (2009). Pedagogic knowledge of future teachers. Capturing and structuring the results of cross-subject teacher education. *Journal of Educational Science 12*(3), 499–527. https://doi.org/10.1007/s11618-009-0085-z

Koehler, M. J., & Mishra, P. (2009). What is technological pedagogical content knowledge (TPACK)? *Contemporary Issues in Technology and Teacher Education, 9*(1), 60–70. https://www.learntechlib.org/primary/p/29544/

Moosbrugger, H., & Kelava, A. (2012). *Testtheorie und Fragebogenkonstruktion*. Springer. https://doi.org/10.1007/978-3-642-20072-4

Petko, D. (2012). Teachers' pedagogical beliefs and their use of digital media in classrooms: Sharpening the focus of the "will, skill, tool" model and integrating teachers' constructivist orientations. *Computers and Education*, *58*(4), 1351–1359. https://doi.org/10.1016/j.compedu.2011.12.013

Rubach, C., & Lazarides, R. (2019). A digital literacy self-assessment scale for student teachers. *Journal for Educational Research*, *9*(3), 345–374. https://doi.org/10.1007/s35834-019-00248-0

Seifried, J., & Wuttke, E. (2016). *Competence development in the context of business education: Programs – Models – Analysis* (pp. 1–18). http://www.bwpat.de/profil4/seifried_wuttke_profil4.pdf

7 Appendix

The german version of the revised scale is available upon request from the author.

Table 1: Comparison of the three constructs of digital technology competence

	DTSE	SWIT	SKL
authors	Hughes, 2013	Doll & Meyer, 2021	Rubach & Lazarides, 2019
Items	17	10	23
digital self-efficacy	✓	✓	x
Collaboration	✓	✓	✓
Safety	✓	✓	✓
technical ability	✓	✓	✓
Softwareusage	✓	x	✓
encouraging learners	x	✓	✓
Confidence in using technology at school	x	✓	✓
teaching	x	✓	✓
reflecting the usage of digital tools	x	x	✓

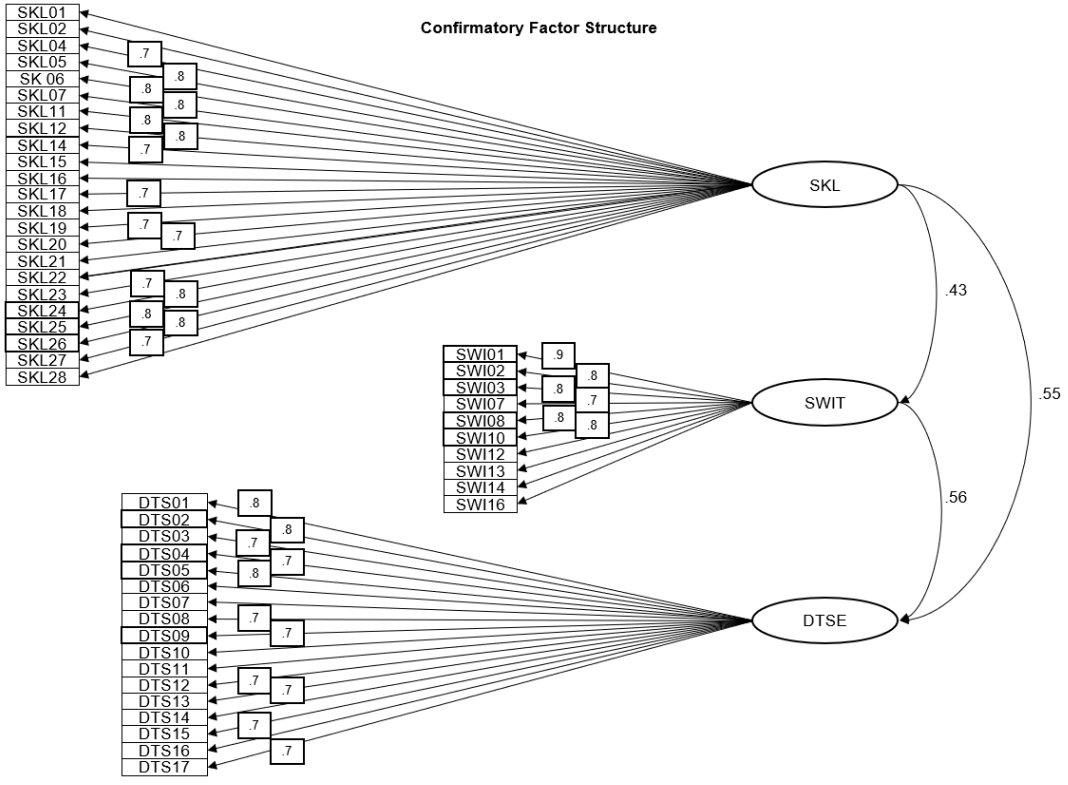

Figure 1: Confirmatory Structure of the tested model