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MEHTODOLOGICAL ISSUES
МЕТОДИЧЕСКИЕ ВОПРОСЫ

Factor Structure of the Russian Version of the "Metacognitive Awareness Inventory"

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Metacognitive processes are important for the success in the wide range of educational activities of youth and young adults. However, the positive correlations between metacognition and academic achievements are not high enough, and the instruments used in these studies might be the reason. We explored the factor structure of the Russian version of the questionnaire "Metacognitive Awareness Inventory" developed by G. Schraw and R. Dennison and adapted by A.V. Karpov and I.M. Skityaeva into Russian. The participants of our study were 527 residents of St. Petersburg, which were studying at the university at the time. Among them there were 366 students getting their first diploma and 161students getting their second diploma (average age 23.8 ± 8.8). In this article the authors present the results of a confirmatory factor analysis of four models, which are the most frequently used in foreign and Russian literature: unidimensional model; two different two-factor models; eight-factor model. Evaluation of the model fit indices for the four models showed that none of them were a god fit. We reduced the number of items of the questionnaire and re-implemented the factor analysis of these four models. The values of indicators of a good model fit improved. In the short version of the questionnaire "Metacognitive Awareness Inventory" the authors discovered two scales – knowledge of cognition and regulation of cognition, which included 8 subscales: declarative knowledge, procedural knowledge, conditional knowledge, planning, information management strategies, comprehension monitoring, debugging strategies, evaluation.

Keywords: education, metacognition, metacognitive processes, metacognitive awareness, factor structure.

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Факторная структура русскоязычной версии опросника «Метакогнитивная включенность в деятельность»

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Исследования метакогнитивных процессов показывают их важность в успешности учебной деятельности юношества и молодежи. Однако положительные корреляции между общими метакогнитивными навыками и академическими достижениями недостаточно высоки, что может быть обусловлено используемым инструментарием. Нами исследована факторная структура русскоязычной версии опросника «Метакогнитивная включенность в деятельность» Г. Шроу и Р. Деннисона, адаптированная А.В. Карповым и И.М. Скитяевой. В исследовании приняли участие 527 жителей Санкт-Петербурга, включенных в учебную деятельность, в том числе 366 студентов и 161 слушатель отделения профессиональной переподготовки (средний возраст 23.8 ± 8.8). Представлены результаты конфирматорного факторного анализа четырех моделей опросника, наиболее используемых в зарубежных и отечественных научных исследованиях: однофакторная модель, две альтернативные двухфакторные модели и восьмифакторная модель. Оценки индексов четырех моделей показали, что ни одна из них не удовлетворяет критериям соответствия. Мы осуществили сокращение количества утверждений опросника и повторно провели факторный анализ четырех указанных моделей, что значительно улучшило критерии соответствия. Сокращенная версия опросника «Метакогнитивная включенность в деятельность» обнаружила двухфакторную структуру шкал: метакогнитивное знание и метакогнитивное регулирование, а также восемь субшкал: декларируемые знания, процедурные знания, условные знания, планирование, стратегии управления информацией, контроль компонентов, структура исправления ошибок и оценка.

Ключевые слова: учебная деятельность, метапознание, метакогнитивные процессы, метакогнитивная включенность, факторная структура.

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Introduction

The latest studies in psychological and educational research are at large part focused on metacognition in learning [7; 34]. J. Flavell was a pioneer in metacognition studies; in the 1980s his followers defined metacognition as a mental activity aimed at investigating the cognitive processes, and active controlling, and management of those processes in order to achieve particular goals [15; 17]. In broad terms metacognition studies in foreign research are dedicated to two types of mental activity: knowledge of cognition (metacognitive knowledge; awareness of one's own cognitive processes) and regulation of cognition (metacognitive regulation; monitoring and control of one's cognitive processes), which are often studied within the framework of the common phenomenon of metacognitive awareness [25; 27; 33]. This concept is currently being developed by researchers from all over the world.

Within the framework of the structural-dialectical approach T.E. Chernokova described the detailed structure of metacognition, including metacognitive knowledge (knowledge of general and individual patterns, objective conditions, and instruments of cognition) and metacognitive processes (control, regulation, and management of the cognition) [9]. The author defined metacognition as a system of one's knowledge about cognitive activity in general and the one's own cognitive processes, as well as the processes that ensure self-regulation of one's cognitive activity [10]. M.A. Kholodnaya proposed a concept of "mental experience", which included involuntary and voluntary intellectual control, an open cognitive position, and metacognitive awareness [8]. Within the framework of the classification of metacognition processes B.M. Velichkovsky described five groups of metastrategies [3], A.V. Karpov defined metacognition as the leading form of reflexive regulation skills [4; 5].

Thus, metacognitive awareness seems to be the main regulating mechanism of cognition and the most important phenomenon of metacognition in Russian and foreign studies [8; 10; 11; 15; 17].

Research on metacognitive awareness in learning shows its predictive power in relation to success of learning. In particular, students with a high level of metacognitive awareness are more successful in problem-based learning [19], getting expert knowledge [14], and have better results in terms of academic achievement [2; 6; 26; 27; 28; 31; 32]. However, positive correlations between general metacognitive skills and academic achievement are not as strong as they could be expected based on theory. Insufficiently strong correlations can be explained by several reasons: firstly, the specifics of the distribution of the general population, in which respondents with low levels of metacognitive skills are located on both sides of the achievement scale [31]; secondly, intermediate variables and/or background factors [16; 13]; finely, the specifics of the used technics [18].

Foreign researchers have investigated the advantages and disadvantages of metacognition questionnaires and concluded that the questionnaires are valuable for practice and large-scale use, but their structure needs improvements [24]. Thus, despite the fact that metacognition has been thoroughly researched, the question about the instruments to measure it remains controversial.

The most popular questionnaire among many existing instruments for metacognitive components assessment is the Metacognitive Awareness Inventory (MAI) created by G. Shrow and R. Dennison to measure knowledge of cognition and regulation of cognition [15; 17; 25]. The authors proposed three different options for calculating the subscales' scores for the questionnaire: (1) an empirical two-dimensional model, (2) a theoretical two-dimensional model, and (3) an eight-dimensional model (Table 1). Later researchers began to use a unidimensional model to calculate the total score of metacognitive awareness.

Table 1

Metacognitive Awareness Inventory and the distribution of items between scales

Items	**Empirical two-dimensional model**	**Theoretical two-dimensional model**	**Eight-dimensional model**
1. I ask myself periodically if I am meeting my goals.	RK	RK	M
2. I consider several alternatives to a problem before I answer.	RK	RK	M
3. I try to use strategies that have worked in the past.	KG	KG	PK
4. I pace myself while learning in order to have enough time.	RK	RK	P
5. I understand my intellectual strengths and weaknesses.	KG	KG	DK
6. I think about what I really need to learn before I begin a task.	RK	RK	P
7. I know how well I did once I have finished a test.	KG	RK	E
8. I set specific goals before I begin a task.	RK	RK	P
9. I slow down when I encounter important information.	KG	RK	IMS
10. I know what kind of information is the most important to learn.	KG	KG	DK
11. I ask myself if I have considered all options when solving a problem.	RK	RK	M
12. I am good at organizing information.	KG	KG	DK
13. I consciously focus my attention on important information.	KG	RK	IMS
14. I have a specific purpose for each strategy I use.	RK	KG	PK
15. I learn best when I know something about the topic.	KG	KG	CK
16. I know what the teacher expects me to learn.	KG	KG	DK
17. I am good at remembering information.	KG	KG	DK
18. I use different learning strategies depending on the situation.	KG	KG	CK
19. I ask myself if there was an easier way to do things after I finish a task.	RK	RK	E
20. I have control over how well I learn.	KG	KG	DK
21. I periodically review to help me understand important relationships.	RK	RK	M
22. I ask myself questions about the material before I begin.	RK	RK	P
23. I think of several ways to solve a problem and choose the best one.	RK	RK	P
24. I summarize what I've learned after I finish.	RK	RK	E
25. I ask others for help when I don't understand something.	KG	RK	DS
26. I can motivate myself to learn when I need to.	KG	KG	CK
27. I am aware of what strategies I use when I study.	RK	KG	PK

Items	**Empirical two-dimensional model**	**Theoretical two-dimensional model**	**Eight-dimensional model**
28. I find myself analyzing the usefulness of strategies while I study.	RK	RK	M
29. I use my intellectual strengths to compensate for my weaknesses.	KG	KG	CK
30. I focus on the meaning and significance of new information.	KG	RK	IMS
31. I create my own examples to make information more meaningful.	KG	RK	IMS
32. I am a good judge of how well I understand something.	KG	KG	DK
33. I find myself using helpful learning strategies automatically.	KG	KG	PK
34. I find myself pausing regularly to check my comprehension.	RK	RK	M
35. I know when each strategy I use will be the most effective.	RK	KG	CK
36. I ask myself how well I accomplish my goals once I'm finished.	RK	RK	E
37. I draw pictures or diagrams to help me understand while learning.	RK	RK	IMS
38. I ask myself if I have considered all options after I solve a problem.	RK	RK	E
39. I try to translate new information into my own words.	KG	RK	IMS
40. I change strategies when I fail to understand.	RK	RK	DS
41. I use the organizational structure of the text to help me learn.	RK	RK	IMS
42. I read instructions carefully before I begin a task.	KG	RK	P
43. I ask myself if what I'm reading is related to what I already know.	RK	RK	IMS
44. I re-evaluate my assumptions when I get confused.	RK	RK	DS
45. I organize my time to best accomplish my goals.	KG	RK	P
46. I learn more when I am interested in the topic.	KG	KG	DK
47. I try to break studying down into smaller steps.	RK	RK	IMS
48. I focus on overall meaning rather than specifics.	RK	RK	IMS
49. I ask myself questions about how well I am doing while learning something new.	RK	RK	M
50.I ask myself if I learned as much as I could have once I have finished a task.	RK	RK	E
51. I stop and go back over new information that is not clear.	KG	RK	DS
52. I stop and reread when I get confused.	KG	RK	DS

Note: KG = knowledge of cognition; RK = regulation of cognition; DK = declarative knowledge; PK = procedural knowledge; CK = conditional knowledge; P = planning; IMS = information management strategies; M = monitoring; DS = debugging strategies; E = evaluation.

The authors who implement English-language version of the questionnaire actively (and independently of each other) use four options for processing the questionnaire: the empirical two-dimensional model of knowledge of cognition (25 items) and regulation of cognition (27 items) [27]; the theoretical two-dimensional model of knowledge of cognition (17 items) and regulation of cognition (35 items) [33]; the eight-dimensional model [22; 30]; and a unidimensional total model of the metacognitive awareness [29].

The Russian-language version of the questionnaire, adapted by A.V. Karpov and I.M. Skityaeva, has a unidimensional factor structure for assessing the total score of metacognitive awareness [5]. However, we identified an eight-factor structure of the questionnaire based on exploratory factorial analysis of empirical data [1; 2].

The purpose of this study is to clarify the factor structure of the Russian-language version of the MAI. The following questions guided this research:

1. Which of the four scoring models used with the MAI (unidimensional model, the empirical two-dimensional model, the theoretical two-dimensional model, the eight-dimensional model), is the best in terms of explaining the pattern of responses?

2. What are the indices of test discrimination and internal consistency of the MAI?

3. What is an optimal set of items of a short version of the MAI and what fit estimates does it have?

Methodology

In this study we used the MAI developed by G. Shrow and R. Dennison, adapted by A.V. Karpov and I.M. Skityaeva into Russian. Each of the questionnaire items is assessed by a respondent using a 5-point Likert scale going from “strongly disagree” to “strongly agree” [5].

Participants and data collection. The sample consisted of 527 respondents (136 men) aged from18 to 39 (M = 23.8 ± 8.8); of which 366 were students of Bachelor program (students getting their first diploma — SGFD) (M = 19.6 ± 1.33) and 161 were students getting their second degree diploma (SGSD) (M = 33.4±5.5) of psychology department of St. Petersburg State University.

Data analysis. To assess the explanatory power of different models for the set of empirical data from Russia we did a confirmatory factor analysis (CFA) using the maximum likelihood restricted [23]. We used the following indicators of a good model fit: Comparative Fit Index (CFI), Tucker—Lewis Index (TLI), Root Mean Square Error of Approximation (RMSEA), Akaike Information Criteria (AIC) and Bayesian Information Criteria (BIC) [12; 20]. Correlation analysis for latent variables of the questionnaire was conducted using Person correlation coefficient. We applied the Item Response Theory (IRT) analysis to the eight-dimensional model of the MAI, which included analyses of both the outfit and infit statistics of Mean-Square Fit Statistics (MNSQ) and correlation items with the score on the scale [21]. The internal consistency of a set of scale items was assessed with Cronbach's alpha. We used Student's t-test for independent groups to evaluate differences between male and female groups, and two groups of students.

Statistical data processing was carried out using STATA.15 and Winsteps software.

Results of the Study

We analysed four models of the factor structure of the MAI (Table 2) on the whole sample.

The CFI and TLI estimates of all four models are below acceptable limits. It should be noted that the latent variables strongly correlated with each other in the presented models: the empirical model (r = 0.897; p < 0.001), the theoretical model (r = 0.922; p < 0.001). The correlation coefficients of the latent variables of the eight-factor model ranged from 0.666 to 0.818 at a significance level of all p < 0.001.

Three items — 42, 43, and 52 — were found to have relatively low factor loadings for all four models (Table 1). These particular items add little information in terms of measuring construct of metacognitive awareness, so we deleted them from subsequent analysis for reasons of maintaining high internal consistency.

IRT analysis of the Metacognitive Awareness Inventory

The analysis of the dimensionality of each of the eight factors of the questionnaire showed that all subscales had a one-dimensional structure. MNSQ values for all items were between 1.5 and 1.9 (all values are less than 2). IRT analysis results determined the average item difficulty of the questionnaire for the whole sample and identified that 18 out of 49 items were problematic: No. 32, 5, 46, 3, 15, 22, 45, 37, 41, 31, 39, 9, 47, 48, 30, 21, 19, 38 (Table 3). The highlighted items disrupted the consistency of the subscales; therefore, they were excluded from further analysis.

Analysis of the factor structure of the short version of the Metacognitive Awareness Inventory

Based on the results of the IRT analysis, a short version of the questionnaire with 32 statements was comprised. CFA was conducted four times to assess the fit of the four models and clarify the scale structure of the shortened version of the MAI (Table 4).

In the short version of the questionnaire multiple model-fitting criteria improved significantly for all four models. The theoretical two-dimensional model and the eight-dimensional model turned out to be the most accurate, as in the case of the full version of the questionnaire. In addition to the RMSE, the values of the output weights the RMSE of our proposed 32-items instrument were inside the normal range, however, CFI and TLI are slightly below the norm.

Table 2

Fit estimates of the Metacognitive Awareness Inventory scoring models

Models	$\chi 2$ (df)	CFI	TLI	RMSEA	AIC	BIC
Unidimensional model	3646.19(1274)	.563	.545	.071	55765	56191
Empirical two-dimensional model	3634.81(1273)	.565	.547	.067	55556	56185
Theoretical two-dimensional model	3532.94(1273)	.584	.567	.066	55454	56083
Eight-dimensional model	3107.34(1145)	.611	.584	.065	53007	53729

Note: df — the degrees of freedom for chi-square; CFI — Comparative Fit Index; TLI — Tucker-Lewis Index; RMSEA — Root Mean Square Error of Approximation; AIC — Akaike information criteria; BIC — Bayesian information criteria.

Table 3

Fit statistics for the Metacognitive Awareness Inventory (IRT)

Subscale	Items	Item difficulty	Standard error	INFIT MNSQ	OUTFIT MNSQ	The correlation of individual item with the subscale
Declarative knowledge	20	1.08	.21	.78	.74	.57
	16	1.03	.22	.93	.92	.63
	12	.64	.23	.79	.76	.65
	17	.59	.23	.72	.66	.57
	32	**-.03**	**.24**	**1.31**	**1.27**	**.43**
	46	**-.77**	**1.2**	**1.25**	**1.30**	**.24**
	5	**-1.15**	**.25**	**1.43**	**1.21**	**.46**
	10	-1.39	.25	1.21	1.24	.46
Procedural knowledge	14	.94	.24	1.23	1.27	.69
	33	.35	.25	.79	.76	.57
	27	.17	.25	.91	1.00	.67
	3	**-1.46**	**.26**	**.95**	.97	.42
Conditional knowledge	35	.65	.23	.84	.82	.63
	18	.45	.23	.70	.68	.58
	15	**-.19**	**.23**	**1.36**	**1.16**	**.52**
	29	1.22	.23	1.22	1.22	.46
	26	-.57	.23	1.08	1.10	.61
Planning	8	.81	.24	.98	.97	.57
	22	**-.39**	**.24**	**1.39**	**1.31**	**.38**
	23	.45	.23	.57	.50	.59
	6	-.91	.24	.84	.83	.65
	4	.61	.23	.98	.98	.54
	45	**-.39**	**.24**	**1.31**	**1.35**	**.42**
Information management strategies	37	1.19	.17	1.41	1.28	.39
	41	.39	.20	.97	1.05	.31
	31	.22	.21	1.29	1.15	.42
	13	.22	.21	1.27	1.15	.46
	30	.35	.20	.89	.95	.60
	39	**.13**	**.21**	**.85**	**.78**	.25
	9	-.53	.24	.92	.93	.22
	47	-.76	.67	.67	.67	.41
	48	-1.22	.24	1.06	1.09	.42
Monitoring	34	1.08	.23	.76	.74	.50
	21	**.72**	**.23**	**1.30**	**1.25**	**.47**
	28	.61	.23	1.23	1.12	.56
	11	.55	.23	1.11	1.16	.64
	49	-.39	.24	.99	1.00	.52
	1	-1.08	.24	.88	.81	.73
	2	-1.49	.24	1.02	.93	.73
Debugging strategies	40	1.12	.23	.78	.79	.69
	44	.46	.24	.82	.81	.71
	25	.00	.24	1.39	1.44	.51
	51	-1.58	.26	1.00	.99	.47
Evaluation	**19**	**1.13**	**.20**	**1.36**	**1.29**	**.56**
	38	**.73**	**.22**	**1.33**	**1.27**	**.52**
	36	.53	.23	.86	.71	.52
	24	.32	.24	1.21	1.10	.47
	7	-.17	.26	1.12	1.15	.50
	50	-1.54	.26	.95	.98	.47

Note: In this table the items with inadequate fit statistics values are highlighted. MNSQ — Mean-Square Fit Statistic; INFIT — Inlier-Pattern-Sensitive Fit Statistic; OUTFIT — Outlier-Sensitive Fit Statistic.

Table 4

Fit estimates of scoring models of the short version of Metacognitive Awareness Inventory

Models	χ2 (df)	CFI	TLI	RMSEA	AIC	BIC
Unidimensional model	21494.46(464)	.810	.799	.054	78148	81002
Empirical two-dimensional model	21467.88(463)	.815	.801	.053	78124	80556
Theoretical two-dimensional model	1442.27(463)	.833	.826	.055	78889	80037
Eight-dimensional model	985.59(329)	.852	.846	.052	78809	79761

Note: df — the degrees of freedom for the chi-square; CFI — Comparative Fit Index; TLI — Tucker—Lewis Index; RMSEA — Root Mean Square Error of Approximation; AIC — Akaike information criteria; BIC — Bayesian information criteria.

The values of Cronbach's alpha for the unidimensional and two-dimensional models are acceptable for psychological questionnaires (Table 5). Cronbach's alpha values for the eight-dimensional model are outside the lower limit of the acceptable range.

Gender and age differences

In the short version of the MAI, the means did not differ significantly in the male and female groups. However, in terms of age, students getting their second degree diploma (M = 54.6±8.8 and M = 45.2±8.4) had significantly higher scores of knowledge of cognition, compared to students of Bachelor program (M = 52±10.3 and M = 42.9±8.9) for both the empirical two-dimensional model (t(525) = -2.69; p = 0.007) and the theoretical two-dimensional model (t(525) = -3.02; p = 0.003). Also, in comparison with students getting their first diploma students getting their second diploma had significantly higher scores of declarative knowledge (M = 19.1±3.6 — for SGSD; M = 18±3.9 — for SGFD; t(525) = -3.42; p = 0.001), conditional knowledge (M = 15.3±3.1 — for SGSD; M = 14.5±3.2 — for SGFD; t(525) = 2.81; p = 0.005) and evaluation (M = 15.9 ± 3.1 for SGSD, M = 14.9 ± 3.3 for SGFD, t(525) = -3.54, p = 0.0004).

Conclusion

The aim of the study was to clarify the factor structure of the Russian version of the MAI questionnaire adapted by A.V. Karpov and I.M. Skityaeva. The CFA and IRT analysis made it possible to exclude some of the items from the questionnaire in order to improve indices of discrimination test of the MAI. The short version of the questionnaire has improved fit estimates of the scoring models. The identified 32-item structure of the questionnaire is consistent with the results of our previous research, in which some items (No. 3, 4, 22, 25, 32, 41, 42) were excluded from the questionnaire based on the results of factor analysis [1; 2], and also matches the short English version of the questionnaire by 80% [18].

The results of the internal consistency reliability test of the subscales of the short version of the MAI demonstrate that the theoretical two-dimensional model is the most acceptable for scientific research and practice. The eight-dimensional model can be used with some limitations due to the low reliability of some scales. In conclusion, the Russian version of the MAI can be shortened since it reproduces the original factorial structure and increase internal consistency.

Table 5

The internal consistency of a set of scale items of scoring models of the short version of Metacognitive Awareness Inventory

Models	Subscales	M (SD) (n = 527)	Cronbach's alpha
Unidimensional model	Total score	120.9±22	.89
Empirical two-dimensional model	Knowledge of cognition	52.8±9.9	.78
	Regulation of cognition	68.1±12.8	.83
Theoretical two-dimensional model	Knowledge of cognition	43.6±8.8	.81
	Regulation of cognition	77.3±13.9	.82
Eight-dimensional model	Declarative knowledge	18.3±3.8	.61
	Procedural knowledge	10.5±2.6	.66
	Conditional knowledge	14.8±3.2	.53
	Planning	15.6±3.2	.51
	Information management strategies	7.7±1.8	.42
	Monitoring	23.0±4.7	.65
	Debugging strategies	15.8±3.2	.53
	Evaluation	15.2±3.3	.56

Appendix

The short Russian version of Metacognitive Awareness Inventory

Instruction

Here are several statements about process of thinking and solving problems. Consider if the statement is true or false as it generally applies to you. Please use the following rate for answer:

1 — strongly disagree
2 — disagree
3 — don't know
4 — agree
5 — strongly agree

	1	2	3	4	5
1. I ask myself periodically if I am meeting my goals.					
2. I consider several alternatives to a problem before I answer.					
3. I pace myself while learning in order to have enough time.					
4. I think about what I really need to learn before I begin a task.					
5. I know how well I did once I have finished a test.					
6. I set specific goals before I begin a task.					
7. I know what kind of information is the most important to learn.					
8. I ask myself if I have considered all options when solving a problem.					
9. I am good at organizing information.					
10. I consciously focus my attention on important information.					
11. I have a specific purpose for each strategy I use.					
12. I know what the teacher expects me to learn.					
13. I am good at remembering information.					
14. I use different learning strategies depending on the situation.					
15. I have control over how well I learn.					
16. I think of several ways to solve a problem and choose the best one.					
17. I summarize what I've learned after I finish.					
18. I ask others for help when I don't understand something.					
19. I can motivate myself to learn when I need to.					
20. I am aware of what strategies I use when I study.					
21. I find myself analyzing the usefulness of strategies while I study.					
22. I use my intellectual strengths to compensate for my weaknesses.					
23. I focus on the meaning and significance of new information.					
24. I find myself using helpful learning strategies automatically.					
25. I find myself pausing regularly to check my comprehension.					
26. I know when each strategy I use will be the most effective.					
27. I ask myself how well I accomplish my goals once I'm finished.					
28. I change strategies when I fail to understand.					
29. I re-evaluate my assumptions when I get confused.					
30. I ask myself questions about how well I am doing while learning something new.					
31. I ask myself if I learned as much as I could once I have finished a task.					
32. I stop and go back over new information that is not clear.					

Scoring Guide

Subscales	Items
Knowledge of cognition	7, 9, 11, 12, 13, 14, 15, 19, 20, 22, 24, 26
Regulation of cognition	1,2, 3, 4, 5, 6, 8, 10, 16, 17, 18, 21, 23, 25, 27, 28, 29, 30, 31, 32
Declarative knowledge	7, 9, 12, 13, 15
Procedural knowledge	11, 20, 24
Conditional knowledge	14, 19, 22, 26
Planning	3, 4, 6, 16
Information management strategies,	10, 23
Monitoring	1, 2, 8, 21, 25, 30
Debugging strategies	18, 28, 29, 32
Evaluation	5, 17, 31, 27

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