https://doi.org/10.22364/atee.2019.itre.15

# DEVELOPMENT OF METACOGNITION AWARENESS SCALE FOR 10TH–12TH GRADE

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**ABSTRACT**

One of the goals of the Latvian National Development Plan is to reduce the proportion of students with low cognitive skills, and at the same time increase the proportion of students with high level cognitive skills by the year 2020. In line with this goal, National Centre for Education has initiated a curriculum and educational assessment system reform. It is important to create assessment instruments for both: subject specific content and 21st century skills, which are integrated in the learning outcomes in the revised curriculum. The aim of this study was to develop and pilot a new metacognitive awareness scale for 10–12 grade pupils. The instrument was based on the structure of the Metacognitive Awareness Inventory (Schraw, & Sperling, 1994), creating new items and making them specific to the content of national level large-scale assessment in Science. A total of 1,257 pupils (48.4% boys, 51.6% girls) aged $M$ = 15.30 ($SD$ = 0.53) participated in the study. To find out the pupils' metacognitive awareness factors, 35 statements about different metacognitive activities were developed. Factor analysis showed good structure of 3 factors – planning, monitoring, and evaluation, but weak structure of other possible factors. Internal consistency of the overall scale was good (α = 0.92). Discrimination and difficulty index levels meet accepted psychometric criteria. After multiple iterations, confirmatory factorial analysis revealed that 9-item model had good fit and good structure of three components: planning, monitoring, and evaluation.

*Keywords: metacognitive awareness inventory, cognition regulation, exploratory and confirmatory factorial analysis.*

## Introduction

Employment distribution over the last years has shifted towards jobs with high and low non-routine skills. High skills encompass problem-solving, abstract reasoning, and decision-making, but low skills demand basic human adaptability (Dorn, 2009). In manufacture, a very similar trend prevails, where a shift  from large numbers of low and medium skilled jobs to smaller number of high skill jobs for the same output is observed (Timmer et al., 2014). There is no lack of jobs in the market, but the jobs being created demand a higher level of skills, than the jobs which have been lost (Wiliam, 2018).

Therefore the Programme for International Student Assessment (PISA) of the Organisation for Economic Co-operation and Development (OECD) states one of the key indicators of the K-12 education system quality the proportion of students which is below Level 1 (students cannot recognise basic aspects or simple phenomenon) and the proportion of students, who have reached Level 4 and Level 5 (students demonstrate full and detailed understanding of phenomenon, abstract and complex thinking skills) (OECD, 2016).

One of the goals in Latvia for the Education Development Plan Year 2014 – Year 2020 of the Ministry of Education is to reduce the proportion of students with low cognitive skills (especially student proportion below Level 1) and at the same time to raise the proportion of students with high cognitive skills. In line with these goals, National Centre for Education has lounched a comprehensive curriculum reform applied to the learning system from kindergarten to the 12$^{th}$ grade, prioritising 21$^{st}$ century skills such as problem solving and critical thinking, communication, collaboration, civic participation, creativity and entrepreneurship, digital literacy and self-regulated learning. The content of the curriculum has been organized in seven learning areas: languages, social sciences, cultural understanding and artistic self-expression, natural sciences, mathematics, technology, and health and physical activity with complex learning outcomes which integrates understanding, skills and attitudes ( Regulations Regarding the State Standard in Basic Education, the Subjects of Study Standards in Basic Education and Model Basic Educational Programmes, 2018).

In the research there is a growing evidence that students with better self-regulated learning skills tend to learn better and with less effort (Zimmerman, 2000). Self-regulated learning consists of controlling learning environment, setting goals, choosing and using appropriate strategies and monitoring progress towards goals. Self-regulated learning consists of three components: cognition, metacognition and motivation. As various authors conceptualize metacognition construct, consisting of two subcomponents: knowledge and regulation of cognition. (Schraw et al., 2006).

Metacognition has been a priority in the research literature as one of the key factors which positively influences student achievements and learning outcomes (Dignath & Büttner, 2008). In the last years scientific studies in the metacognition examines not only laboratory settings, but also classroom settings (Veenman & Alexander, 2011).

In additional metacognitive knowledge and skills seem to be related to the successful transfer of learning and deeper problem pattern recognition. When experts find themselves in a new situation without specific knowledge and experience, they are prone to use a more general strategy to solve the problem. Self-knowledge can be both a facilitator and a constraint in such situations. There are several interconnections between metacognitive knowledge, learning, teaching, and assessing, which are difficult to separate. Most often teachers assume that students could acquire metacognitive knowledge on their own, but in this case this assumption is wrong. Only some students are able to acquire metacognitive knowledge through experience. However even a separate course is not an effective way to develop metacognitive skills. Such strategies should be embedded in the subject practice. In terms of assessment, its process is more informal and is revealed through conversation and observation. In some cases, it is possible to use more structured interviews and questionnaires (Pintrich, 2002).

Effectiveness of metacognition in student learning outcomes and well-being is firmly stated in research, but there is little evidence that schools are using such metacognition strategies universally. The central goal is to understand the effect of use and assessment of metacognitive strategies with the view to improve student learning outcomes (Perry et al., 2019). The key distinguished criteria between students who use metacognitive skills and students who don't is a consciousness way to solving new problems. When students are confronted with a new novel problem they cannot rely on the algorithm. Students who often find themselves in an unknown situation should apply and use more general strategies. Marcel Veenman has extensively studied relation between intelligence and metacognition, he claims that it is possible to teach metacognition from primary school to university and certain conditions promote metacognitive skill acquisition. Metacognition should be embedded in the curriculum, explaining to the pupils the aim of metacognition and metacognitive skill learning should be extended over longer period of time (Van der Stel & Veenman, 2014).

Metacognition allows people to solve novel problems in new contexts and every subject can benefit from metacognition teaching. Schools are trying to use innovative solutions, in order to maximize student progress. There is also a need for greater focus on research and development of tools to measure metacognition, primarily for the screening purpose. Metacognition promotion has specially big positive effect for disadvantageous students' learning outcomes (Perry et al., 2019).

There are Several categorizations of metacognition. One of the problem in research literature is that different constructs are inconsistent and lack coherence (Zohar & Barzilai, 2013). One of the greatest debates revolves over the question whether metacognition is domain general or domain specific. Studies reveal, that it is both domain specific and domain general. It depends highly on the context, especially on the age of the students. Recent studies state that metacognitive skills have a tendency to generalize over time (Zohar & Barzilai, 2013). According to the authors' systematic review, there is a tendency of growing of research studies in metacognition, especially in more specific domain circumstances, and even in finer grain structure, for example Newtons mechanics (Zohar & Barzilai, 2013).

First signals showed that young children are quite unaware of their cognition phenomena or metacognition. They do relatively little memory, comprehension and other processes monitoring (Flavell, 1979). According to Flavell, monitoring of cognitive processes occurs as four cognitive phenomena: metacognitive knowledge, metacognitive experience, goals or tasks and metacognitive strategies (Flavell, 1979). In real life situations, metacognition is rather concerned with the extent to how much you should believe in an idea or do what it says, and not how well you understand it.

One of the concerning questions is that studies in metacognition predominately are conducted among older students. The evolution of professional development of in and pre service teachers in the field of metacognitive knowledge about instruction is still under research (Zohar & Barzilai, 2013).

## Aim of the Study

The aim of this study was to develop a new metacognitive awareness inventory for 10-12 grade pupils for screening purposes. For this reason, two data analysis were conducted, with the following research questions:

1) does the structure of a new inventory meet psychometric criteria and forms of metacognitive component i.e. factors of regulation of cognition?
2) does the determined factors of metacognition are confirmed by empirical data?

## Materials and Methods

### Participants

A total of 1,524 pupils (49.6% boys, 50.4% girls) aged 15 to 16 years, *M* = 15.30 (*SD* = 0.54) participated in the study and completed Metacognitive Awareness Inventory. After clearing data of incomplete inventories, data of 1257 pupils (48.4% boys, 51.6% girls) aged 15 to 16 years, *M* = 15.30, (*SD* = 0.53) was used in analysis (14-year-olds were 69.38 %, and 15-year-olds 30.62 %). Students from 60 schools in Latvia participated in the study. On average, pupils from each school were

$M$ = 20.6, $SD$ = 14.77 (median $n$ = 16). Average time for completing the inventory was $M$ = 5.60 minutes ($SD$ = 5.41, median $n$ = 5). Differences between gender samples were only in three items however the differences were minor (Cohen's d 0.23 [95% CI: 0.12, 0.34], so further data analysis was done across the whole sample.

### Instruments

35 items were developed based on the idea of original 52-items Metacognitive Awareness Inventory (Schraw & Dennison, 1994 by permission of auth. Dennison) with an aim to create short instrument of MA evaluation. New items were created and made specific to the content of national level large scale-assessment in Science, according to the new curriculum. Items were arranged in 5 subcomponents of regulation of cognition as in the original inventory: 1) planning — planning, goal setting, and allocating resources prior to learning (f.e. "I read instructions carefully before I begin a task"); 2) monitoring – assessment of one's learning or strategy use (f.e. "I find myself analysing the usefulness of strategies while I study"); 3) evaluation – analysis of performance and strategy effectiveness after a learning episode (f.e. "I ask myself if I have considered all options after I solve a problem"; 4) information management – skills and strategy sequences used online to process information more efficiently (e.g. organizing, elaborating, summarizing, selective focusing)(f.e. "I slow down when I encounter important information"); 5) debugging – strategies used to correct comprehension and performance errors (f.e. "I stop and reread when I get confused"). The survey response scale was in 6-point Likert scale from "never" to "always".

### Procedure

The survey was given to pupils right after they had completed the test in natural science during second semester of 2019. Survey was filled online immediately after the test. Inventory items were divided into 3 blocks and before each block, there a were specific instructions given about before, during and after tasks (Maitland et al., 2015). For example: "Now, there will be a number of statements about what you thought you were thinking about before you started to perform tasks", thus extending it to the planning phase. Inventories were completed in large groups, classroom setting right after completing the test. Students used the instrument's standard response format – rating each item using a 5-point Likert-type scale: 1 (never), 2 (seldom), 3 (sometimes), 4 (often), and 5 (always). The instrument took less than 30 minutes to complete. The few students who chose not to participate in completing the instruments were given a book to read.

## Data analysis

In order to answer the questions of the research, the indices of total item correlations or discrimination and reaction or difficulty were analyzed, as well the internal consistency. Subsequently, a factor analysis (EFA) was performed. Finally, the structure of the obtained factors was tested by confirmatory factor analysis (CFA). JASP data processing software was used.

## Results

To answer the first research question, initial descriptive analysis of items were calculated (Table 1) to test item reaction and discrimination indices. Reaction indexes were $M = .59$ $SD = .22$ (.33 – .80) (recommended $> .6$), corrected item total correlation .15 – .62 (recommended .30-.70). All items were decided to be appropriate for inclusion in the EFA. Internal consistency was calculated by Cronbach's criterion and for all scale α was .92. Before the factor analysis, appropriateness of the data for the factor analysis was analysed via Kaiser-Meyer-Olkin (KMO) and Barlett Sphericity test. KMO value of the scale was .92 which means that data are appropriate for the factor analysis (Barrett & Morgan, 2005). Bartlett's test of sphericity, which shows multivariate normality, was significant ($\chi^2(595) = 13508$, $p < .001$). Factorial analysis with varimax rotation was conducted. Factors were initially retained based on consideration of the eigenvalues and the amount of variance explained. After removing the unfit items, the structure of the factors improved, leaving the clearer structure of three components. Items relevant to information management and debugging strategies were inappropriate. However, data analysis showed that a three-factor model was appropriate. A three-factor solution (with eigenvalues over 1.0) explained 43.98% of the variance. The first factor explained 28.09% of the variance, the second factor explained an additional 9.47% of the variance and the third factor 6.42% of the variance as well.

In order to answer the second research question, confirmatory factorial analysis was conducted. With CFA it is possible to explore how the measurement model which operationalizes the theoretical factor structure fits a set of empirical data (Harrison & Vallin, 2018). To evaluate the fit of the models, criteria recommended in Hu & Bentler (1999) was used where adequate models typically exceed .90 on the global comparative fit index (CFI) and the Tucker-Lewis index (TLI) and well-fitting models have CFI and TLI estimates greater than .95 with the root mean square error of approximation (RMSEA) less than .06. To compare the models, maximum likelihood estimation was used. Factorial analysis was based on three-component model: planning, monitoring, and evaluation. To identify the best set of items, CFA was made in multiple iterations.

**Table 1.** Descriptive statistics of MAI version

| | Mean | SD | Diffi-culty | Discrim-ination | Skew-ness | SE | Kurtosis | SE |
|---|---|---|---|---|---|---|---|---|
| Item 1 | 4.12 | 1.39 | .69 | .44 | -0.241 | 0.069 | -0.755 | 0.138 |
| Item 2 | 3.86 | 1.295 | .64 | .53 | -0.147 | 0.069 | -0.539 | 0.138 |
| Item 3 | 3.3 | 1.281 | .55 | .52 | 0.262 | 0.069 | -0.47 | 0.138 |
| Item 4 | 4.66 | 1.277 | .78 | .45 | -0.667 | 0.069 | -0.327 | 0.138 |
| Item 5 | 3.37 | 1.363 | .56 | .50 | 0.205 | 0.069 | -0.677 | 0.138 |
| Item 6 | 4.81 | 1.209 | .80 | .39 | -0.715 | 0.069 | -0.441 | 0.138 |
| Item 7 | 1.99 | 1.164 | .33 | .36 | 1.254 | 0.069 | 1.299 | 0.138 |
| Item 8 | 4.8 | 1.149 | .80 | .17 | -1.118 | 0.069 | 1.115 | 0.138 |
| Item 9 | 2.42 | 1.298 | .40 | .39 | 0.774 | 0.069 | 0.036 | 0.138 |
| Item 10 | 3.73 | 1.403 | .62 | .43 | -0.094 | 0.069 | -0.746 | 0.138 |
| Item 11 | 3.69 | 1.432 | .62 | .42 | -0.202 | 0.069 | -0.685 | 0.138 |
| Item 12 | 3.11 | 1.247 | .52 | .60 | 0.352 | 0.069 | -0.299 | 0.138 |
| Item 13 | 3.98 | 1.353 | .66 | .50 | -0.187 | 0.069 | -0.788 | 0.138 |
| Item 14 | 3.47 | 1.298 | .58 | .62 | 0.076 | 0.069 | -0.613 | 0.138 |
| Item 15 | 3.75 | 1.333 | .63 | .55 | -0.008 | 0.069 | -0.779 | 0.138 |
| Item 16 | 2.7 | 1.364 | .45 | .38 | 0.545 | 0.069 | -0.417 | 0.138 |
| Item 17 | 3.95 | 1.365 | .66 | .17 | -0.534 | 0.069 | -0.477 | 0.138 |
| Item 18 | 4.47 | 1.312 | .75 | .47 | -0.475 | 0.069 | -0.674 | 0.138 |
| Item 19 | 3.52 | 1.273 | .59 | .56 | 0.099 | 0.069 | -0.592 | 0.138 |
| Item 20 | 3.45 | 1.476 | .58 | .52 | 0.141 | 0.069 | -0.896 | 0.138 |
| Item 21 | 3.78 | 1.216 | .63 | .57 | 0.009 | 0.069 | -0.483 | 0.138 |
| Item 22 | 3.39 | 1.263 | .57 | .25 | 0.105 | 0.069 | -0.56 | 0.138 |
| Item 23 | 3.6 | 1.209 | .60 | .53 | 0.163 | 0.069 | -0.465 | 0.138 |
| Item 24 | 3.57 | 1.303 | .60 | .45 | 0.068 | 0.069 | -0.553 | 0.138 |
| Item 25 | 3.72 | 1.269 | .62 | .46 | 0.012 | 0.069 | -0.601 | 0.138 |
| Item 26 | 2.86 | 1.4 | .48 | .33 | 0.391 | 0.069 | -0.693 | 0.138 |
| Item 27 | 3.55 | 1.308 | .59 | .44 | 0.018 | 0.069 | -0.555 | 0.138 |
| Item 28 | 3.3 | 1.283 | .55 | .52 | 0.113 | 0.069 | -0.473 | 0.138 |
| Item 29 | 2.91 | 1.298 | .49 | .40 | 0.474 | 0.069 | -0.191 | 0.138 |
| Item 30 | 3.06 | 1.317 | .51 | .43 | 0.247 | 0.069 | -0.51 | 0.138 |
| Item 31 | 3.94 | 1.379 | .66 | .15 | -0.476 | 0.069 | -0.53 | 0.138 |
| Item 32 | 3.07 | 1.327 | .51 | .46 | 0.299 | 0.069 | -0.49 | 0.138 |
| Item 33 | 3.12 | 1.387 | .52 | .48 | 0.233 | 0.069 | -0.638 | 0.138 |
| Item 34 | 3.01 | 1.271 | .50 | .53 | 0.293 | 0.069 | -0.441 | 0.138 |
| Item 35 | 3.53 | 1.376 | .59 | .51 | 0.043 | 0.069 | -0.633 | 0.138 |

SE – standard error

As Table 2 shows, the first 5 models indicate that none met the criteria for adequate fit. The factorial model with each subsequent iteration was improved after several iterations of item elimination. At the 6$^{th}$ iteration after 23 items had been eliminated, best criteria was met. The model functioned adequately (based on the criteria that adequate models have CFI and TLI $>$ .95). In this 9-item model, the global fit indices indicated good model fit (CFI = .966, TLI = .949, RMSE = .059 [95% CI: .049-.069]), and the chi-square test was still significant ($\chi 2 = 131$, df = 24, $p < .001$). Final iteration resulted in 9 items (Appendix 1) that had good fit in CFA models and clear structure of 3 components: planning, monitoring, and evaluation.

**Table 2.** Iterative models of CFA of Short Metacognitive Awareness Scale items

| | | | | | | RMSEA 90% CI | |
|---|---|---|---|---|---|---|---|
| **Iteration** | **N of items** | **CFI** | **TLI** | **SRMR** | **RMSEA** | **Lower** | **Upper** |
| 1 | 32 items | .807 | .784 | .057 | .065 | .063 | .067 |
| 2 | 30 items | .841 | .820 | .053 | .061 | .059 | .064 |
| 3 | 21 items | .888 | .864 | .044 | .063 | .059 | .067 |
| 4 | 14 items | .916 | .885 | .043 | .068 | .063 | .074 |
| 5 | 11 items | .936 | .908 | .038 | .068 | .060 | .076 |
| 6 | 9 items | .966 | .949 | .026 | .059 | .049 | .069 |

## Conclusions

There is a lack of credible empirical data for the more than three factor model of metacognition and instruments tend to be more inaccurate than the fine-grained theoretical descriptions (Pintrich et al., 2000). Overall evaluation of the Short Metacognition Awareness Scale (SMAS) which captures only one component of metacognition shows that it has three main components of regulation of cognition (Table 3). The Components include planning, monitoring and evaluation factors. Items relevant to information management and debugging strategies were unappropriated and excluded from the inventory. This structure is similar to the two-component structure suggested by other researches of regulation of cognition (Brown, 1987; Flavell, 1987; Jacobs & Paris, 1987). Confirmatory factorial analysis revealed that 9-item model had good fit and good structure of 3 components: planning, monitoring, and evaluation. Our provisional conclusion is that this 9-item subset will function equally well in sample of 10–12 graders. According to the initial development results SMAS instrument is convenient for the teachers' use in classroom for screening purposes without overburden for the students and without time consumption. Authors argue that metacognition regulation should be assessed during the teaching and learning process to develop better teacher practices and student awareness of metacognition regulation.

Further research is necessary to develop and validate instruments in different grades in order to establish convergent and discriminant validity for use in school for the whole K-12 education. The next steps will determine the relevance of the instrument to specific aspects of science subjects as well in other learning areas.

As with all research studies, this study has limitations. The sample is more homogeneous in terms of students, because it is based on schools which participate in new curriculum development, which brings school focus on the 21st century skills. But at the time of starting the research, the school curriculum did not include teaching metacognitive skills, and thus one can assume that the ability to reflect on their own cognition was not developed explicitly. in the further research, it is very important to find out which metacognitive components predict better student achievement in different subjects.

**Table 3.** Short Metacognitive Awareness Scale statements

| Component | Statement |
|---|---|
| Planning | I consider problem solving strategy before I begin a task |
| Planning | I consider several alternatives to a problem before I begin a task. |
| Planning | I think of several ways to solve a problem and choose the best one. |
| Monitoring | I ask myself if I have considered all options when solving a problem. |
| Monitoring | I ask myself questions about how well the problem-solving strategy is during the task. |
| Monitoring | I find myself pausing regularly to check my comprehension. |
| Evaluation | I ask myself how well I accomplish my goals once I'm finished |
| Evaluation | I ask myself if I have considered all options after I solve a problem. |
| Evaluation | I ask myself if I completed as much as I could have once I finish a paper. |

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