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RESEARCH ARTICLE

The Relationship between Metacognition, Learning Flow, and Problem-Solving Ability of Dental Hygiene Students

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Background: This study aims to improve dental hygiene education by investigating the relationship between metacognition, learning flow, and problem-solving abilities in dental hygiene majors.

Methods: A survey was conducted on 2nd to 4th-year students from dental hygiene programs, with 132 responses analyzed. Data analysis involved t-tests and ANOVA to examine the differences in metacognition, learning flow, and problem-solving abilities based on the general characteristics. Multiple regression analysis was employed to investigate the factors influencing the dependent variable, which is problem-solving abilities. The collected data were analyzed using SPSS.

Results: First, when comparing metacognition, learning flow, and problem-solving abilities based on the general characteristics of the study participants, statistically significant differences were observed in common factors such as major satisfaction, subjective academic performance, GPA (grade point average), and reason for major choice ($p<0.05$). Second, it was found that there is a significant positive correlation between metacognition, learning flow, and problem-solving abilities in dental hygiene students ($r\geq0.79$, $p<0.05$). In other words, higher levels of metacognition and learning flow were associated with better problem-solving abilities. Third, factors influencing problem-solving abilities were identified, with both metacognition and learning flow having a statistically significant positive impact. It was also noted that metacognition had a greater influence on problem-solving abilities compared to learning flow (adjusted $R^2=0.815$, $p<0.05$).

Conclusion: To enhance the core competency of problem-solving abilities, it is essential to improve metacognition and learning flow. To enhance metacognition and promote learning flow, strategies such as goal setting, utilizing effective learning methods, boosting self-efficacy, managing the learning environment, choosing activities that foster immersion, stress management, self-assessment and feedback integration, improving focus, and utilization a variety of learning experiences will be necessary.

Key Words: Dental hygiene, Learning flow, Metacognition, Problem-solving ability

Introduction

1. Background

In recent times, there has been significant interest in self-assessing personality using tools like the MBTI (Personality Type Assessment) in South Korea. This trend has drawn attention to metacognition as a factor related to self-objectification. MBTI assists in objectifying and understanding an individual's personality type, while metacognition can contribute to developing awareness and self-perception related to this understanding.

Metacognition refers to the notion of 'cognition about cognition' or 'self-awareness.' It includes the concept of monitoring and managing one's learning progress, signifying the mental process of observing, discovering, and controlling one's cognitive processes from a higher level of perspective, which involves a heightened awareness of one's own cognitive processes[1]. In essence, it is the awareness related to intelligence that involves calmly recognizing what one knows and doesn't know, strategizing to identify and resolve issues independently, and being able to regulate one's learning journey. It has been primarily

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studied in conjunction with concepts like problem-solving abilities, especially among students[1].

Problem-based learning (PBL) is an instructional method predominantly used in the field of education, distinguishing itself from traditional lecture-centric teaching approaches. In PBL, students engage with real-world problems or scenarios, embarking on a journey of self-directed and collaborative learning to find solutions to these challenges. Throughout this process, they autonomously acquire the necessary knowledge and skills[2]. PBL proves to be an effective educational method that enhances students' collaboration skills, critical thinking, communication skills, creativity, and applied skills[2]. As a result, numerous educational institutions and universities have adopted PBL to improve students' learning experiences and enhance learning outcomes.

Problem-solving ability represents the highest level of cognitive function, involving the mental process of identifying, collecting, and reviewing data and information to find solutions to problems in any given situation. It encompasses the ability to judiciously select and organize specialized knowledge acquired through learning[3]. Metacognition and problem-solving ability are crucial in the sense that they involve awareness of what information is needed and what skills are required to solve problems and the ability to reflect on the outcomes obtained in the process[4]. Learners with strong metacognitive skills are aware of when to employ metacognitive strategies and can select alternative approaches for defining problem situations and solving them.

Learning flow signifies not only the emotional contentment associated with enjoyable learning but also the potential to enhance the quality of learning[5,6]. Metacognition and self-directed learning have a significant impact on learning flow, with self-directed learning playing a crucial mediating role in the relationship between metacognition and learning flow[7]. Lee[8] emphasized the significant relationship between the cognitive strategies employed by individuals during the learning process and the experience of flow among students. Moreover, it was noted that the more frequently metacognition is employed, the greater the likelihood of experiencing a heightened sense of flow during the learning process.

According to prior research studies, Kang et al.[9] argued that metacognition significantly influences flow and problem-solving abilities. Sternberg[10] suggests that successful problem-solving can be achieved by continuously monitoring during the problem-solving process, emphasizing the necessity of metacognitive functions. Levine and Wang[11] points out that students with well-developed metacognitive self-regulation skills consistently apply various problem-solving methods while effectively utilizing previously learned concepts. In contrast, students with lower self-regulation skills tend to adhere to a single problem-solving approach regardless of its effectiveness.

Previous research in the field of healthcare and medical sciences suggests that is reported that metacognition and learning flow have a close relationship with problem-solving abilities[12-14].

According to previous studies in the field of dental hygiene, Yu et al.[15] investigated general characteristics and major-related traits to understand the factors influencing dental hygiene students' problem-solving abilities. Additionally, Kim et al.[16], Shim et al.[17], and Jun and Kim[18] conducted research on critical thinking tendencies and problem-solving abilities. Additionally, in the field of dental hygiene, factors such as metacognition[19], interpersonal skills[20], self-efficacy[21], and PBL[22] have been researched for their impact on problem-solving abilities. Kang and Kim[23] argued that metacognition is not only related to problem-solving abilities but also associated with learning flow, critical thinking, and self-directed learning. They emphasized the increasing importance of critical thinking and comprehensive problem-solving abilities for dental hygienists in response to contemporary demands. Meanwhile, studies targeting dental hygiene students have primarily explored their academic achievements in relation to learning flow[24,25].

Furthermore, in various fields, research on metacognition, learning flow, and problem-solving abilities among students is being conducted. However, the dental hygiene field still lacks substantial research on metacognition, learning flow, and problem-solving abilities. Therefore, there is a need to develop strategies for curriculum and teaching methods to enhance the educational environment for the advancement of dental hygiene education. Additionally, there is a need to explore approaches for cultivating the essential competency of problem-solving abilities required in clinical practice as dental hygienists.

2. Objectives

Therefore, the purpose of this study is to understand the relationship between metacognition, learning flow, and problem-solving abilities among dental hygiene major students, and to identify the factors that influence problem-solving abilities. Through this research, we aim to provide fundamental data that can contribute to the improvement of teaching methods and educational environments in dental hygiene education.

Materials and Methods

1. Subjects and ethics statement

This study was conducted online from September 10, 2023, to September 14, 2023, using a convenience sample extraction method in undergraduate students in their 2nd, 3rd, and 4th years majoring in dental hygiene across the country. First-year students were excluded. The survey was conducted through an online questionnaire with individuals who understood the research objectives and voluntarily agreed to participate. The online survey involved respondents accessing the survey link via URL and providing self-reported responses. This study received research approval from the Institutional Review Board of Namseoul University (202307-004).

2. Study design

The calculation of the required sample size for this study was performed using the G*power 3.1.9.4 program. Considering a moderate effect size of 0.15, a significance level of 0.05, a power of 0.95, and the inclusion of up to 2 independent variables, the necessary sample size was estimated to be 107 individuals. However, since this study involved a non-face-to-face survey conducted via URL, accounting for unfaithful responses and a dropout rate of 10% to 20%, the final target sample size was set at 130 participants. As a result, data from 132 respondents who completed the survey were used as the final dataset for analysis.

3. Study variables

The tools used in this study consisted of a total of 100 items, including metacognition (31 items), learning flow (29 items), problem-solving abilities (32 items), and general characteristics (8 items). Among the dental hygiene students who participated in this study, the average metacognition score was 2.14±0.51 points, learning flow was 2.37±0.65 points, and problem-solving abilities were 2.26±0.53 points. Among the sub-components, self-regulation was the highest in metacognition, with a score of 2.29±0.48 points. In learning flow, the sub-components of self-loss of consciousness scored the highest at 2.62 ± 0.93 points, followed by self-directed experiences at 2.53±0.91 points. Among the sub-components of problem-solving abilities, self-control scored the highest at 2.58±0.50 points (Table 1).

1) Metacognition

The metacognition tool used in this study was adapted from the MSLQ (Motivated Strategies for Learning Questionnaire) developed by Pintrich et al.[26] to measure learning strategies. It was restructured to include 31 items related to the cognitive and metacognitive domains. The 5 sub-factors included practice, elaboration, organization, critical thinking, and self-regulation. Respondents rated each item on a 5-point Likert scale. Higher scores indi-

Table 1. Variables and Subfactors

Variables	Item	Score	Cronbach's α
Metacognition	31	2.14±0.51	0.907
Practice	4	2.03±0.72	0.732
Elaboration	6	1.99±0.59	0.652
Organization	4	2.01±0.66	0.596
Critical thinking	5	2.14±0.67	0.691
Self-regulation	12	2.29±0.48	0.697
Learning flow	29	2.37±0.65	0.940
Challenge-skills balance	3	2.14±0.70	0.646
Clear goals	3	2.10±0.79	0.590
Specific feedback	3	2.17±0.78	0.696
Action-awareness merging	3	2.42±0.87	0.703
Task concentration	3	2.43±0.82	0.699
Sense of control	3	2.39±0.81	0.647
Loss of self-consciousness	3	2.62±0.93	0.708
Altered sense of time	3	2.39±0.86	0.754
Autotelic experience	5	2.53±0.91	0.849
Problem-solving ability	32	2.26±0.53	0.918
Approach avoidance style	16	2.22±0.55	0.849
Problem-solving confidence	11	2.16±0.66	0.870
Self-control	5	2.58±0.50	0.591

Values are presented as mean±standard deviation.

cated a higher level of metacognition. In previous studies, the Cronbach's α for each of the 5 sub-factors ranged from 0.64 to 0.80, while in this study, it was found to be Cronbach's α=0.907 (Table 1).

2) Learning flow

The learning flow instrument consisted of a total of 29 items, as proposed by Csikszentmihalyi[5], and modified and improved by Kim et al.[6]. It comprises nine sub-factors: challenge-skills balance, clear goals, specific feedback, action-awareness merging, task concentration, sense of control, loss of self-consciousness, altered sense of time, and autotelic experience. Participants responded to each item using a Likert 5-point scale, ranging from 'strongly disagree' 1 point to 'strongly agree' 5 points. A higher score indicates a stronger sense of learning flow. In prior research, the Cronbach's α for each of the nine sub-factors ranged from 0.65 to 0.90. In this study, the Cronbach's α was calculated as 0.940 (Table 1).

3) Problem-solving ability

The problem-solving ability instrument used in this study was adapted from the Personal Problem-Solving Inventory, originally developed by Heppner and Petersen[3] and culturally adapted for our context by Kang et al.[9]. The questionnaire comprises a total of 32 items, organized into three sub-factors: approach avoidance style, problem-solving confidence, and self-control. Participants responded to each item using a Likert 5-point scale. A higher score indicates a higher level of problem-solving ability. In previous research, the Cronbach's α values for the three sub-factors were reported as follows: avoidance style 0.72, problem-solving

Table 2. General Characteristics of the Subject

Characteristic	Division	n (%)
Total		132 (100.0)
Age	≤21 y	58 (43.9)
	>21 y	74 (56.1)
Sex	Male	13 (9.8)
	Female	119 (90.2)
School type	College	27 (20.5)
	≥University	105 (79.5)
Grade	2nd	49 (37.1)
	3rd	65 (49.2)
	4th	18 (13.6)
Major satisfaction	Very satisfied	38 (28.8)
	Satisfied	90 (68.2)
	Dissatisfied	4 (3.0)
	Very dissatisfied	0 (0.0)
Subjective academic performance	Excellent	33 (25.0)
	Good	63 (47.7)
	Moderate	30 (22.7)
	Poor	6 (4.5)
	Very poor	0 (0.0)
GPA	≥4.0	43 (32.6)
	<4.0~≥3.0	85 (64.4)
	<3.0~≥2.0	4 (3.0)
	<2.0	0 (0.0)
Reason for major choice	Based on academic performance	9 (6.8)
	Based on the recommendation of others (parents or teachers)	23 (17.4)
	Due to high employment prospects after graduation	56 (42.4)
	Because it seemed suitable for my aptitude	44 (33.3)
	Other	0 (0.0)

GPA: grade point average.

confidence 0.85, and self-control 0.90. In the present study, the Cronbach's α value was calculated as 0.918 (Table 1).

4) General characteristics

General characteristics were composed of a total of 8 items, including age, sex, school type, grade, major satisfaction, subjective academic performance, grade point average (GPA) and reasons for choosing the major.

The participants in this study, who were majoring in dental hygiene, had an average age of 21.92 (±1.49) years, with the majority being females (90.2%). Most of the participants were enrolled in universities (79.5%), with 3rd-year students comprising the largest group (49.2%), followed by 2nd-year students (37.1%), and 4th-year students (13.6%). Regarding major satisfaction, 97% expressed satisfaction or higher. Subjective academic performance was reported as good (47.7%), excellent (25.0%), moderate (22.7%), and poor (4.5%). In terms of the previous semester's GPA, the distribution was as follows: 3.0 or higher but less than 4.0 (64.4%), 4.0 or higher (32.6%), and 2.0 or higher but less than 3.0 (3.0%). The reasons for choosing the major were ranked as follows: good job prospects after graduation (42.4%), suitability for the field (33.3%), influence or recommendation from parents, teachers, or others (17.4%), and alignment with academic performance (6.8%) (Table 2).

4. Statistical methods

A descriptive statistical analysis was conducted on the general characteristics of the study subjects. Independent two-sample t-tests and one-way ANOVA were used to investigate differences in metacognition, learning flow, and problem-solving abilities based on the participants' general characteristics. Post-analysis was performed using Scheffe's multiple comparison test. Multiple regression analysis, using the Enter method, was employed to identify factors influencing problem-solving abilities, the dependent variable. The collected data were analyzed using the PASW Statistics version 23.0 (IBM Corp., Armonk, NY, USA) program, with a statistical significance level set at α=0.05.

Results

1. Differences in metacognition, learning flow, and problem-solving abilities according to general characteristics

The results of the comparison of the relationship among metacognition, learning flow, and problem-solving abilities based on the general characteristics of the study participants are presented in Table 3. Commonly, statistically significant differences were observed in metacognition, learning flow, and problem-solving abilities based on general characteristics such as major satisfaction, subjective academic performance, GPA and reasons for choosing the major ($p < 0.05$).

Differences in metacognition based on general characteristics were found to be statistically significant for school type, major satisfaction, subjective academic performance, GPA and reasons for choosing the major ($p < 0.05$).

Differences in learning flow based on general characteristics were found to be statistically significant for age, major satisfaction, subjective academic performance, GPA and reasons for choosing the major ($p < 0.05$).

Differences in problem-solving abilities based on general characteristics were found to be statistically significant for school type, major satisfaction, subjective academic performance, GPA and reasons for choosing the major ($p < 0.05$).

2. Correlations between metacognition, learning flow, and problem-solving abilities

The analysis of the correlation among metacognition, learning flow, and problem-solving abilities in dental hygiene major students revealed statistically significant relationships ($p < 0.05$). Metacognition ($r=0.88$, $p < 0.01$) and learning flow ($r=0.82$, $p < 0.01$) demonstrated significant positive correlations with problem-solving abilities (Table 4).

3. Factors Influencing problem-solving abilities

Multiple regression analysis was conducted with problem-solving ability as the dependent variable and metacognition and learning flow as independent variables (Table 5). The Durbin-Watson test resulted in a value of 2.333, which is close to 2, indicating that the multiple regression model is appropriate. Furthermore, the tolerance and variance

Table 3. Difference in Metacognition, Learning Flow, Problem-Solving Ability according to General Characteristics (n=132)

Characteristic	Division	n (%)	Metacognition		Learning flow		Problem-Solving ability	
			M±SD	t/F (p)	M±SD	t/F (p)	M±SD	t/F (p)
Age	≤21 y	58 (43.9)	1.94±0.47	−4.275 (0.995)	2.00±0.65	−6.595 (0.006)	1.99±0.52	−5.508 (0.199)
	>21 y	74 (56.1)	2.29±0.48		2.66±0.49		2.46±0.44	
Sex	Male	13 (9.8)	2.00±0.52	−1.048 (0.706)	2.25±0.61	−0.699 (0.414)	2.17±0.57	−0.579 (0.656)
	Female	119 (90.2)	2.15±0.50		2.38±0.66		2.27±0.53	
School type	College	27 (20.5)	2.12±0.29	−0.222 (<0.001)	2.43±0.65	0.599 (0.626)	2.21±0.40	−0.504 (0.007)
	≥University	105 (79.5)	2.14±0.55		2.35±0.66		2.27±0.56	
Grade	2nd	49 (37.1)	2.11±0.48	0.875 (0.419)	2.32±0.67	0.811 (0.447)	2.21±0.55	1.125 (0.328)
	3rd	65 (49.2)	2.19±0.51		2.44±0.66		2.32±0.53	
	4th	18 (13.6)	2.02±0.57		2.25±0.59		2.14±0.47	
Major satisfaction	Very satisfied	38 (28.8)	1.83±0.49^{b}	12.658 (<0.001)	1.92±0.63^{b}	15.987 (<0.001)	1.94±0.53^{a}	11.307 (<0.001)
	Satisfied	90 (68.2)	2.25±0.46^{ab}		2.53±0.58^{ab}		2.38±0.48^{a}	
	Dissatisfied	4 (3.0)	2.52±0.28^{a}		2.95±0.35^{a}		2.46±0.19^{a}	
	Very dissatisfied	0 (0.0)	-		-		-	
Subjective academic performance	Excellent	33 (25.0)	2.00±0.60^{b}	3.876 (0.011)	1.98±0.67^{c}	15.676 (<0.001)	2.03±0.64^{b}	6.233 (0.001)
	Good	63 (47.7)	2.10±0.48^{b}		2.28±0.56^{bc}		2.22±0.50^{ab}	
	Moderate	30 (22.7)	2.26±0.38^{ab}		2.81±0.46^{ab}		2.50±0.33^{ab}	
	Poor	6 (4.5)	2.67±0.38^{a}		3.17±0.47^{a}		2.67±0.32^{a}	
	Very poor	0 (0.0)	-		-		-	
GPA	≥4.0	43 (32.6)	1.78±0.30^{b}	22.481 (<0.001)	1.89±0.52^{c}	27.275 (<0.001)	1.84±0.33^{b}	28.753 (<0.001)
	≥3.0 to <4.0	85 (64.4)	2.30±0.50^{a}		2.56±0.57^{b}		2.46±0.49^{a}	
	≥2.0 to <3.0	4 (3.0)	2.58±0.28^{a}		3.32±0.50^{a}		2.56±0.34^{a}	
	<2.0	0 (0.0)	-		-		-	
Reason for major choice	Based on academic performance	9 (6.8)	2.01±0.48^{b}	22.594 (<0.001)	2.25±0.70^{b}	16.165 (<0.001)	2.15±0.46^{bc}	24.246 (<0.001)
	Based on the recommendation of others (parents or teachers)	23 (17.4)	2.70±0.49^{a}		2.96±0.57^{a}		2.83±0.41^{a}	
	Due to high employment prospects after graduation	56 (42.4)	2.17±0.39^{b}		2.45±0.58^{b}		2.31±0.45^{b}	
	Because it seemed suitable for my aptitude	44 (33.3)	1.83±0.39^{b}		1.97±0.51^{b}		1.91±0.41^{c}	
	Other	0 (0.0)	-		-		-	

By t-test or one-way ANOVA.

GPA: grade point average, M: mean, SD: standard deviation.

[a,b,c]Different letter indicates are significant differenceat α=0.05 by Scheffe test.

inflation factor for all variables were between 0.1 and 10, confirming that there was no issue of multicollinearity, and the regression model was statistically significant ($F=290.146$, $p<0.001$).

The analysis results revealed that both metacognition and learning flow had statistically significant positive effects on problem-solving ability (adjusted $R^2=0.815$, $p<0.05$). In conclusion, it was found that problem-solving ability increases as metacognition and learning flow levels increase.

Discussion

1. Interpretation

In this study, we assessed the levels of metacognition, learning flow, and problem-solving ability among dental hygiene major university students. We analyzed data from 132 participants who were in their 2nd, 3rd, and 4th years of study to examine the impact of metacognition and learning flow on problem-solving ability. The study uncovered key factors affecting problem-solving skills, indicating that both metacognition and learning flow significantly contributed to a positive impact, explaining 81.5% of the variance.

Table 4. Correlations between Metacognition, Learning Flow and Problem-Solving Ability

Coefficient	Metacognition	Learning flow	Problem-solving ability
Metacognition	1		
Learning flow	0.79**	1	
Problem-solving ability	0.88**	0.82**	1

By person's correlation analysis at $\alpha=0.05$, **$p<0.01$.

2. Key results and comparison

The levels of metacognition, learning flow, and problem-solving ability in this study were as follows: metacognition 2.14±0.51, learning flow 2.37±0.65, and problem-solving ability 2.26±0.53 (Table 1). When compared to prior studies targeting engineering freshmen, where metacognition was at 3.14±0.41, flow was at 3.20±0.53, and problem-solving ability was at 3.19±0.38, it appears that the average scores of dental hygiene students in this study were significantly lower[27]. Additionally, in a study conducted with fourth-year nursing students, metacognition was at 3.32±1.31, learning flow was at 2.93±0.09, and problem-solving ability was at 3.37±0.06[14]. Once again, the scores of dental hygiene students in this study seem to be lower. Furthermore, in a study involving dental hygiene students from the first to the third year, metacognition was at 4.43±0.76 on a 7-point scale, and problem-solving ability was at 2.82±0.54 on a 5-point scale[28]. When compared to these results, it is evident that the participants in this study had lower average scores. Since this study focused on second, third, and fourth-year students, excluding freshmen, it may be challenging to make direct comparisons with studies targeting engineering freshmen or fourth-year nursing students. Therefore, it may be beneficial to compare the levels of metacognition, learning flow, and problem-solving ability by year. Additionally, considering that metacognition is sometimes measured on a 7-point scale in other studies, it is essential to make comparisons on the same scale for a more accurate assessment.

The general characteristics of the study participants in this research indicated that there was a slight discrepancy between students' subjective and objective academic performance (Table 2). Although 32.6% of students achieved

Table 5. Factor related to Problem-Solving Ability

Factor	B	SE	β	t	p	Multicollnearity	
						Tolerance	VIF
(constant)	0.229	0.087		2.632	0.010		
Metacognition	0.664	0.064	0.633	10.416	<0.001	0.381	2.622
Learning flow	0.257	0.049	0.318	5.223	<0.001	0.381	2.622
$R=0.905$, $R^2=0.818$, adjusted $R^2=0.815$, $F=290.146$, $p<0.001$, Durbin-Watson=2.333							

By multiple regression analysis at $\alpha=0.05$.
VIF: variance inflation factor.

a GPA of 4.0 or higher, only 25.0% perceived their academic performance as excellent subjectively. Conversely, while only 3.0% of students had a GPA between 2.0 and 3.0, 4.5% considered their academic performance to be poor. This can be related to metacognition. Metacognition involves the ability to objectively recognize what one knows and doesn't know, identify and solve problems independently, and control the learning process[1]. In this study, dental hygiene students' metacognition levels were relatively low, with a mean score of 2.14±0.51. Therefore, it can be interpreted that their ability to self-assess their academic performance was lower, possibly contributing to the observed differences.

The analysis comparing the relationship between metacognition, learning flow, and problem-solving abilities based on the general characteristics of the study participants revealed statistically significant differences in metacognition, learning flow, and problem-solving abilities for all four factors: major satisfaction, subjective academic performance, GPA and reasons for choosing the major ($p<0.05$; Table 3).

In the case of major satisfaction, the dissatisfaction group showed significantly higher levels of metacognition and learning flow compared to the very satisfied group ($p<0.05$; Table 3). Nam and Kim[14] classified major satisfaction into good, moderate, and bad categories, where the good category had higher metacognition and learning flow than the bad category, and the good category had higher problem-solving abilities than the moderate category. This differs from the results of our study. In our study, 97% of the participants were satisfied with their major, while only 3% were dissatisfied. This difference in group size may have influenced the results.

In the case of subjective academic performance, the results indicate that individuals who perceive their grades as poor and those with a previous semester's GPA below 4.0 tend to have higher levels of metacognition, learning flow, and problem-solving abilities ($p<0.05$; Table 3). Park and Cho[29] found that non-cognitive factors such as grit and subjective grades have a more significant impact on core competencies than cognitive factors like GPA. This suggests that even if actual grades are low, perceiving oneself as having high grades can have a positive influence on core competencies. However, in the current study, it is noted that 97% of the participants had actual grades of 3.0 or above, whereas 72.7% of them perceived their grades as excellent or very excellent. This suggests that the participants in this study tend to perceive themselves as having lower grades than they actually achieve. Jeoun[30] conducted a problem-solving-based college life adaptation program and found that college life adaptation, problem-solving abilities, and intrinsic motivation improved, but self-esteem did not show significant improvement. However, it was argued that psychological aspects, such as self-esteem and self-efficacy, need to improve together in order to predict the continuous improvement and maintenance of metacognition. Therefore, in this study as well, it is suggested that additional research is needed to complement psychological and non-cognitive aspects that allow individuals to assess themselves accurately from a learning perspective.

In terms of the reasons for choosing their major, the group that chose their major based on the recommendation of others (such as family or teachers) showed significantly higher levels of metacognition, learning flow and problem-solving abilities compared to the other groups ($p<0.05$; Table 3). In a study conducted on dental hygiene college students regarding metacognition and problem-solving abilities, it was found that the motivation behind choosing dental hygiene and academic satisfaction had a significant impact on metacognition. However, no significant difference was observed in problem-solving abilities. Among the motivations for choosing dental hygiene, those who wanted to become dental hygienists (4.66±0.70) had the highest metacognition scores, while those influenced by recommendations from others (4.08±0.81) had the lowest metacognition scores[28]. According to previous research, having a subjective goal of wanting to become a dental hygienist, rather than choosing the field due to recommendations from others, was associated with higher metacognition scores. However, in the current study, it was found that those who chose their major based on recommendations from others had higher scores in metacognition, learning flow, and problem-solving abilities. This discrepancy in results may be due to the diverse reasons individuals choose to study dental hygiene, and interpreting these findings solely

based on these aspects may be challenging. Therefore, further research with additional variables is needed to validate and better understand these differences.

The dental hygiene students showed significant positive correlations among metacognition, learning flow, and problem-solving abilities ($p < 0.05$; Table 4), which aligns with previous research findings[13,14]. In other words, it was found that higher levels of metacognition and learning flow were associated with better problem-solving abilities, consistent with the results of previous studies.

The results of the multiple regression analysis conducted to identify the factors influencing problem-solving abilities, the dependent variable, showed that both metacognition and learning flow had significant positive effects. Moreover, it was found that metacognition had a greater impact on problem-solving abilities compared to learning flow (adjusted $R^2=0.815$, $p < 0.05$; Table 5). It's interesting to note that the findings of this study regarding the impact of metacognition and learning flow on problem-solving abilities align with the results of Oh and Kang's study[13], which showed that only learning flow influenced problem-solving abilities. Similarly, Jeoun's study[30] also found that learning flow, metacognition, and subjective grades were factors affecting problem-solving abilities, which is consistent with the results of this study. On the other hand, Jun et al.'s study[28] reported no correlation between metacognition levels and problem-solving abilities among dental hygiene college students, which differs from the findings of this study. These discrepancies might be attributed to differences in the study populations, methods, or other variables, and they highlight the complexity of understanding the relationships between metacognition, learning flow, and problem-solving abilities. Further research may be needed to explore these discrepancies and potential contributing factors. Indeed, as indicated by previous research, there is a wide range of teaching and learning methods being employed to enhance problem-solving abilities. However, the diversity in research findings suggests the need for the development of effective pedagogical strategies aimed at improving problem-solving abilities. Moreover, it is important to validate the effectiveness of these strategies when applied in the context of dental hygiene education. The field of dental hygiene may benefit from tailored approaches that align with the specific demands and challenges of the discipline. Conducting research to assess the impact of these teaching methods on problem-solving abilities in dental hygiene students would be a valuable endeavor, potentially leading to more targeted and effective educational practices in this field. Such research could contribute to the continuous improvement of dental hygiene education and ultimately enhance the quality of care provided by future dental hygienists. Meanwhile, Kahney[31] explained that metacognition is encompassed within problem-solving, and Heppner and Petersen[3] as well as Kapa[32] have demonstrated a strong correlation between problem-solving ability and metacognition, describing metacognition as a subcomponent of problem-solving abilities. In Jeoun's study[30], it was also argued that metacognition is not a separate element from problem-solving but rather an essential strategic component within problem-solving abilities. When compared to these previous studies, the current research findings align with the idea that metacognition significantly influences problem-solving abilities.

In conclusion, it was confirmed that metacognition and learning engagement significantly influence the problem-solving abilities of dental hygiene students.

3. Suggestion

To enhance the core competency of problem-solving abilities, it is essential to improve metacognition and learning flow. This can provide efficient and effective learning experiences, as well as sustain motivation and interest in continuous learning. To enhance metacognition and promote learning flow, strategies such as goal setting, utilizing effective learning methods, boosting self-efficacy, managing the learning environment, choosing activities that foster immersion, stress management, self-assessment and feedback integration, improving focus, and utilization a variety of learning experiences will be necessary.

4. Limitations

The limitations of this study include the diverse tools used to measure metacognition, learning flow, and problem-solving abilities. Particularly, the scale points for metacognition varied between 7-point and 5-point scales. Add-

itionally, there is a scarcity of research in the dental hygiene field that addresses metacognition, learning flow, and problem-solving abilities together, which posed limitations when comparing the results of this study with existing literature. Future research should consider a more extensive and diverse sample of dental hygiene majors, aiming to investigate differences in results among various sub-factors.

Additionally, it should be noted that the study was conducted on a limited and unspecified number of participants for the purpose of this research, which may affect the generalizability of the results. Therefore, further research should consider conducting comparative analyses between students from institutions that implement PBL and those that do not, to provide a more comprehensive understanding of the outcomes.

Nevertheless, despite these limitations, it is evident that universities need to develop diverse educational courses and tailored programs to match the characteristics of their target audience for the advancement of the university and the support and management of adult learners. Furthermore, the significance of this study lies in the confirmation that metacognition and learning flow are essential for enhancing problem-solving abilities and sustaining academic performance and management among dental hygiene majors.

Notes

Conflict of interest

No potential conflict of interest relevant to this article was reported.

Ethical approval

This study was approved by the Namseoul University Bioethics Review Committee (IRB NSU-202307-004).

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Data availability

Please contact the corresponding author for data availability.

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