JOURNAL OF BALTIC SCIENCE EDUCATION
ISSN 1648-3898 /Print/
ISSN 2538-7138 /Online/

IMPROVING SCIENCE PROCESS SKILLS OF STUDENTS WITH MILD INTELLECTUAL DISABILITIES

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Abstract: *Relevant literature has an unexplored question on how prediction-observation-explanation (POE) worksheets affect science process skills of students with mild intellectual disabilities (SMID). Therefore, this research aimed to examine the effect of POE worksheets developed for the "matter and its nature" subject on SMID's science process skills. Through pre-experimental research design, 12 fifth grade SMID participated in the research. To collect data, the researchers used science process skills development forms and rubrics to score their observations. During the teaching intervention, SMID implemented three POE worksheets, which included buzz 22 technique in the 'prediction' stage, hands-on experiments and QR codes in the 'observation' stage and snowball, learning gallery or card showing techniques in the 'evaluation' stage. The results indicated that the POE worksheets are effective at developing SMID's science process skills of the "matter and its nature" subject. This research recommends that future comparative research should unveil how the POE worksheets with/without active learning techniques impact the SMID's SPS.*

Keywords: *Mild intellectual disabilities, science education, science process skills*

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Introduction

Special education serves to diagnose any special needs and develop proper learning environments for meeting the needs of students with special learning disabilities. Of these diagnosed groups, students with intellectual disabilities are prevalent worldwide (e.g., 1-3% for developed countries) (McConkey et al., 2016; Petterson et al., 2007). Although intellectual disabilities can be divided into several categories (mild, moderate, severe and profound), most of them fall into the 'mild' category (nearly 85%) (King et al., 2009). These students learn slowly due to their limited abilities (Boyle & Scanlon, 2009; Gligorović & Buha, 2013; Mascolo-Glosser, 2015; MoNE, 2018; Stavroussi et al., 2016; Villanueva et al., 2012). However, they can develop some skills, behaviours, attitudes and knowledge if teaching methods and special education programmes in resource rooms are well-designed and planned (Dessemontet & Bless, 2013; Meral, 2015; Spooner et al., 2011; Stefanic et al., 1996; Villanueva et al., 2012). For example, Türker-Yıldırım (2022), who systematically reviewed 17 Turkish research papers concerning science teaching for students with intellectual disabilities, addressed that they could learn related concepts, knowledge and skills of science course after specialized teaching interventions. In addition, she stressed that these students need more time and enriched instructional materials to achieve better science learning.

Special education teachers and science teachers' difficulties in developing specialized teaching materials undermine science learning of students with mild intellectual disabilities (SMID) (Denizli & Uzoğlu, 2014). This means that they need to be exposed to an enriched science learning environment (Gündüz & Akın, 2015; Mete et al., 2017; Türker-Yıldırım, 2022). However, given previous research and systematic reviews, little research has focused on science learning of SMID (Comarú et al., 2021; Jimenez et al., 2012; Knight et al., 2013; McGinnis, 2013; Spooner et al., 2011; Şenel Çoruhlu et al., 2021, 2022; Tosun, 2022; Türker-Yıldırım, 2022). For example, Tosun (2022), who analyzed 100 articles regarding science education for students with special needs, found that little research was conducted on students with intellectual disabilities. Similarly, Comarú et al. (2021), who reviewed 119 articles

https://doi.org/10.33225/jbse/23.22.323

ISSN 1648–3898 /Print/
ISSN 2538–7138 /Online/

on inclusive education in science education, reported that only 17% of them focused on students with cognitive or intellectual disabilities. They also emphasized that much more research is needed to share the results with the scientific community and effectively illustrate inclusive processes. Interestingly, relevant literature has an unexplored question on how prediction-observation-explanation (POE) worksheets affect SMID's science process skills (SPS). SPS engages SMID in hands-on and minds-on activities that facilitate their science learning and involve scientific processes (Dhillon, 1996; Karsli-Baydere et al., 2020; Rillero, 1998; Scharmann, 1989). Thereby, SMID can transfer their SPS to daily-life issues and employ them to meaningfully conceptualize any scientific phenomenon around them. Because SMID frequently encounters SPS through science course (Brigham et al., 2011), SPS is viewed as an expected learning outcome for them. That is, SMID, at least, improves observation and classification skills after attending a science course (Mastropieri & Scruggs, 1992). For this reason, SPS has a pivotal role in underpinning SMID's further learning and making their science learning sustainable. Therefore, given the significance of SPS in SMID's science learning, the current research purposed to fill in an important gap in the related literature. Thus, it may give some insights into how to improve SMID's SPS and illustrate how to pedagogically enrich the resource rooms.

Theoretical Framework: Science Process Skills

One of the main goals of science education is to equip students with SPS (Germann et al., 1996; Lakhvich, 2021) that facilitates conceptual understanding of SMID via daily life experiences/practices (King et al., 2008; Kujawinski, 1997; Myers et al., 2004). Further, SMID has an opportunity to learn scientific ways/methods used by scientists (Dhillon, 1996; Karsli-Baydere et al., 2020). That is, SPS intertwines 'doing science' with 'knowing science (as science content)' (Rillero, 1998). Phrased differently, science activities (e.g., POE worksheets) integrating SPS into science content help students properly capture SPS and conceptual understanding (Karsli-Baydere et al., 2020; Scharmann, 1989).

Even though the current literature incorporates some different classifications of SPS, it mainly consists of basic and integrated process skills (Burns et al., 1985; Brotherton & Preece, 1996; Germann & Aram, 1996; Morrison, 2012; Padilla, 1990; Rambuda & Fraser, 2004; Rubin & Norman, 1992). Basic process skills act as a pre-request for scientific research and underpin integrated process skills (Ango, 2002; Beaumont-Walters & Soyibo, 2001; Brotherton & Preece, 1996; Germann & Aram, 1996; Meador, 2003; Padilla, 1990; Rambuda & Fraser, 2004; Rubin & Norman, 1992; Saat, 2004). Since basic process skills are seen as the indicator of intellectual development (Padilla, 1990), students are expected to acquire them in the first years of elementary school (Brotherton & Preece, 1996; Morisson, 2012). Therefore, the current research embedded basic process skills (e.g., predicting, observing and classifying) within the POE worksheets to help SMID develop these skills. Meanwhile, integrated process skills (e.g., formulating hypotheses, identifying and controlling variables, and experimenting) are necessary to develop and achieve scientific inquiry and practices (Kujawinski, 1997; Yıldırım et al., 2016). Since students with intellectual disabilities mostly have problems using cognitive and metacognitive strategies (Geary et al., 1991), integrated process skills should be simplified and concretized to afford SMID to effectively use their working memory (Turner & Bray, 1985). The current research considered this suggestion for the development of the POE worksheets and the selection of active learning techniques. In other words, it attempted to specialize the POE worksheets given the features of SMID. Thus, it tried to empower SMID's SPS given Vygotsky's zone proximal development. That is, it was expected that SMID could develop SPS better if the distance between the actual developmental level and the level of potential development is well-planned (Vygotsky, 1978).

The intervention studies, which employed student-centred experiments (German et al., 1996; Turpin, 2000), collaborative learning (Bozdoğan et al., 2006), inquiry-based learning (Kaya & Yilmaz, 2016), POE activities (Marzuki, 2019; Smith et al., 2010; Yulianti et al., 2018; Zhao et al., 2021) and laboratory activities (Reynders et al., 2019) to develop SPS, showed significant improvements in the participants' SPS. Given their results, this research hypothesized that the POE worksheets enriched with active learning techniques would cultivate SMID's SPS and afford them to associate their gained knowledge with daily life.

https://doi.org/10.33225/jbse/23.22.323

Research Aim

The aim of this research was to examine the effect of POE worksheets developed for the "matter and its nature" subject on SMID's SPS.

Research Methodology

General Background

This research employed a pre-experimental research design to examine the extent to which the POE worksheets affect SMID's SPS of the "matter and its nature" subject. A lack of a control group may be seen as the limitation of the research. However, because the current research did not intend to compare the experimental group's SPS with the control one, it preferred a pre-experimental research design (Candaş & Çalik, 2022; Kiryak & Çalik, 2018). Also, it considered the experimental group's pre-test scores as a starting point to identify any improvement in SMID's SPS. Further, it deployed Cliff's delta value, as an objective criterion (effect size), to overcome any criticism of the pre-experimental research design (Cliff, 1993).

Participants

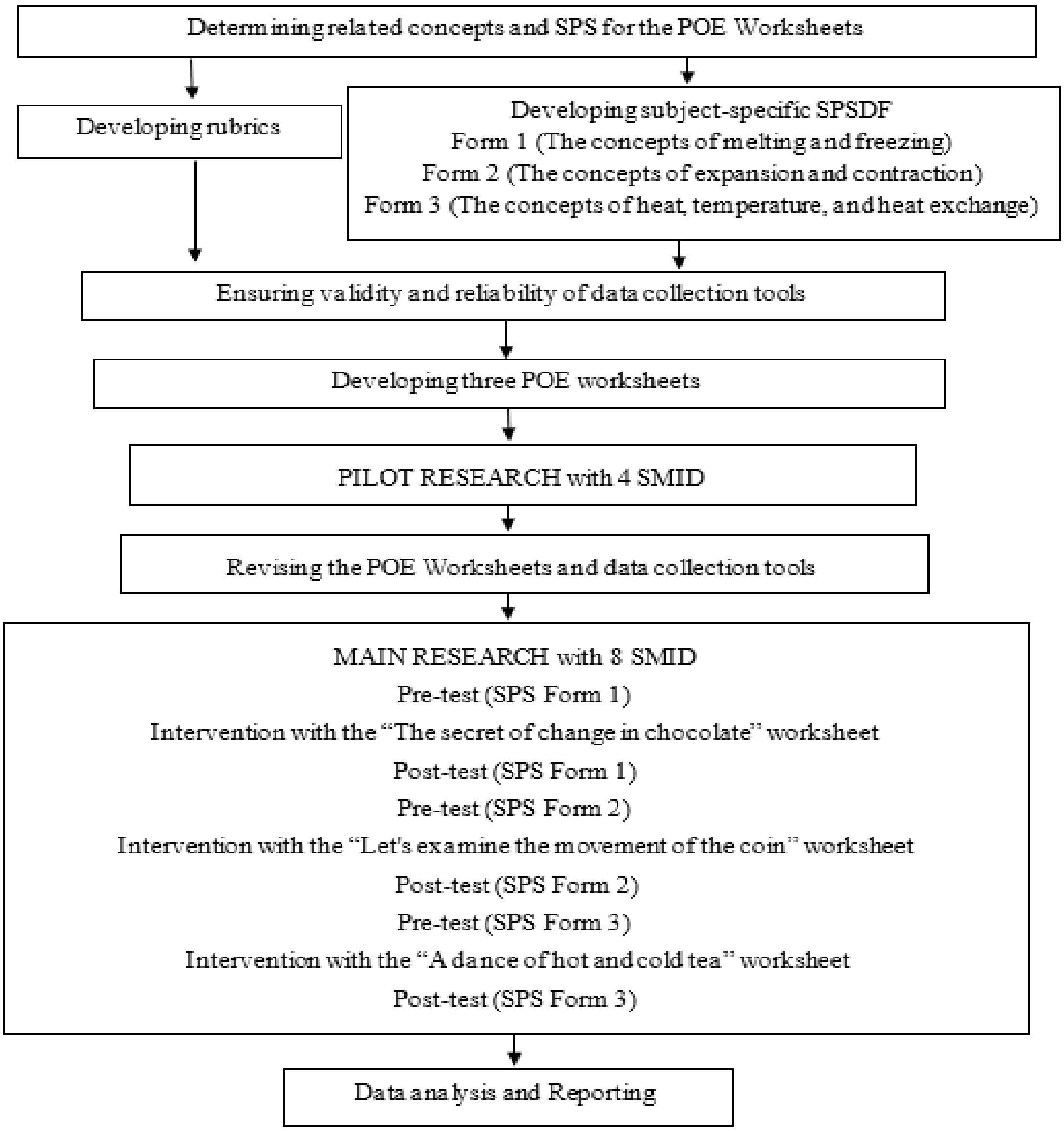
12 fifth grade SMID (3 girls and 1 boy for the pilot research; 4 girls and 4 boys for the main research), who were purposefully selected from the population (n=181) in the city of Trabzon, participated in the research. The portfolios supplied by the guidance and counselling services of the schools indicated that all participants possessed medical and educational diagnoses. According to these diagnostic reports, students with intellectual disabilities, whose intelligence scores were between 50 and 69 based on the diagnostic and statistical manual of mental disorders, were named SMID. The main research was carried out in the fall semester of the 2019-2020 academic year, whilst the pilot one was implemented in the spring semester of the 2018-2019 academic year. Nevertheless, the pilot and main research focused on the same diagnosed group (SMID) but they were implemented in different state schools. Given research ethics, the researchers used pseudonym names for the students. Four of them had attended the resource rooms since 2018 (Oya, Berk, Ada and Nur), whilst Cem, Ali, Emre and Ece had taken this service since 2011, 2013, 2014 and 2015 respectively. Only one of them (Ece) had not attended any resource room. Furthermore, majority of them took mathematics (Ada, Ece, Nur, Oya, Berk, Cem, Emre), and Turkish (Ada, Ece, Nur, Berk, Cem, Emre, Ali) courses at the resource rooms, whilst 5 of them (Ada, Oya, Ece, Nur, Berk) attended science. Figure 1 summarizes the research procedure.

Students with special needs take science course in resource rooms, which are typically designed for special education to improve their learning or academic performance (academic achievement, and social interaction) (Gut & Safran, 2002; Holahan & Costenbader, 2000). Further, teachers should prepare and implement individualized lesson plans in resource rooms by considering the needs of students with special learning disabilities. Hence, they intend to meet their own students' educational needs, which are not handled in regular classrooms (Friend & Bursuck, 2009).

https://doi.org/10.33225/jbse/23.22.323

ISSN 1648–3898 /Print/
ISSN 2538–7138 /Online/

Figure 1
A Flowchart for the Research Procedure



Context

Given the "melting, freezing, expansion, contraction, heat, temperature, and heat exchange" concepts in the "matter and its nature" subject, the researchers developed three POE worksheets (named "the secret of change in chocolate," "let's examine the movement of the coin" and "a dance of hot and cold tea") including active learning techniques (e.g., Buzz 22, snowball technique, and learning gallery), QR codes and hands-on experiments. Buzz 22 (which asks two students to discuss the topic or concept or question for two minutes), learning gallery (which encourages students to revise, list and evaluate their gained knowledge or learning outcomes) and snowball (which fosters students to examine a topic in their small groups of 2 and then requests them to generate larger groups to discuss their results, ideas and arguments with more peers) were used to stimulate SMID's learning motivation, and peer-to-peer or teacher-to-student interactions. Similarly, card showing asks them to use the cards to indicate whether they agree or disagree with the presented idea. Likewise, QR code enables them to reinforce their gained

https://doi.org/10.33225/jbse/23.22.323

ISSN 1648–3898 /Print/
ISSN 2538–7138 /Online/

knowledge/skills and revise what they have learned. Also, hands-on experiments require them to do experiments that pose related SPS and conceptual understanding (Kızılarslan et al., 2021; Nicol et al., 2022).

Unlike a normal worksheet, the POE worksheets were specialized for SMID by including simple, short and understandable guidelines. For instance, snapshots and visual representations were added into the guidelines to enhance the comprehensibility and followability of the POE worksheets. In a similar vein, active learning techniques and experiments were taken special care to make them easily applicable and accessible. For example, daily-life words and materials/tools were used in the POE worksheets. Since SMID needs to reinforce what they have learned (Friend, 2006), QR codes were embedded within the POE worksheets to get them to watch the related experiments over and over. Finally, the POE worksheets included SMID's avatars to increase their feelings of belonging. Table 1 outlines related concepts, focused SPS, stages and techniques in regard to the POE worksheets.

Table 1
Related Concepts, Focused SPS, Stages and Techniques in Regard to the POE Worksheets

WS	Related concepts	Focused SPS	Stages of the worksheet	Stages of the POE	Active learning techniques/ experiments	QR codes Link
The secret of change in chocolate	Melting, and freezing	Predicting, Formulating Hypotheses, Interpreting Data, Inferring, Experimenting, Observing	Attracting attention	Prediction	Buzz 22	
			Activity	Observation	Experiment of melting-freezing	https://youtu.be/zBCGjku-6DiA
			Evaluate	Explanation	Snowball	
					Card showing	
Let's examine the movement of the coin	Expansion and contraction	Formulating Hypotheses, Inferring, Predicting, Classifying, Interpreting Data, Controlling variables, Communicating, Experimenting, Observing	Attracting attention	Prediction	Buzz 22	
			Activity	Observation	Experiment of expansion and contraction	https://youtu.be/QGnK7mC-QXvE
			Evaluate	Explanation	Snowball	
					Card showing	
A dance of hot and cold tea	Heat, temperature, and heat exchange	Predicting, Formulating Hypotheses, Interpreting Data, Inferring, Communicating, Classifying, Experimenting, Observing, Using Numbers	Attracting attention	Prediction	Buzz 22	
			Activity	Observation	Experiment of heat exchange	https://youtu.be/d2beUScJV6M
			Evaluate	Explanation	Snowball	
					Learning gallery	

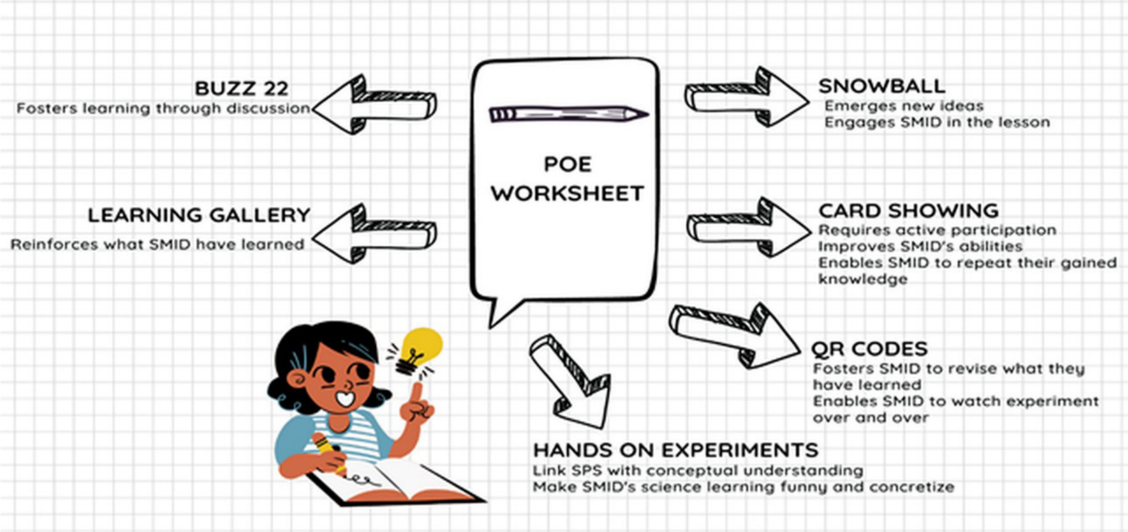
Note. WS – worksheet

The first stage of each POE worksheet purposed to draw their attention and asked them to make a prediction. They conducted the experiments and wrote down their observations on the worksheets if necessary. Finally, they were required to explain any consistency or inconsistency between their predictions and observations. Hence, the third stage of each worksheet requested them to make an evaluation. As seen from Table 1, the researchers embedded active learning techniques, QR codes and experiments within the stages of the POE worksheets. Figure 2 outlines the advantages of the active learning techniques (buzz 22, snowball, learning gallery, and card showing), QR codes and experiments. Figures S1-3 illustrate the POE stages of the worksheet entitled "let's examine the movement of the coin" (see Supplementary Material).

https://doi.org/10.33225/jbse/23.22.323

ISSN 1648–3898 /Print/
ISSN 2538–7138 /Online/

Figure 2
The Advantages of the Active Learning Techniques (buzz 22, snowball, learning gallery, and card showing), QR Codes and Hands-on Experiments



Instrument and Procedures

To collect data, the researchers improved three SPS development forms (SPSDF) focusing on formulating hypothesis, inferring, predicting, classifying, interpreting data, controlling variables, communicating, experimenting and observing (Kujawinski, 1997). These forms asked SMID to conduct hands-on experiments, which contained different materials/objects for the same concepts at the worksheets. For example; whilst the worksheet "let's examine the movement of the coin" exploited a coin, SPSDF used a balloon to handle the concepts of "expansion and contraction". Figure S4 illustrates the targeted SPS for the concepts of "expansion and contraction" (see Supplementary Material).

Prior to the data collection and implementation processes, the parents were informed about the research procedure and asked to sign the consent form. Only SMID, whose parents signed the consent form, took part in the research. Also, the researchers obtained the ethics committee approval from Karadeniz Technical University (Number: 82554930/01-554). Further, they got official permission from the Directorate of National Education in Trabzon. Later, the researchers videotaped SMID's experimental performances before and after the implementation of each worksheet. Table 2 displays the focused SPS and relevant questions in regard to the SPS forms.

Table 2
Focused SPS and Relevant Questions in Regard to the SPS Forms

SPS Forms	SPS	Questions
Form 1	Formulating hypotheses	What can you prove using these materials?
	Inferring	Which phases of butter appear after the heating? Please explain your reason(s).
	Predicting	What do you do to observe solid and liquid phases of butter?
	Interpreting data	What happens when heating the butter? What happens when cooling the butter?
	Communicating	How can you tell your gained knowledge/experience to your friend?
	Experimenting and observing	* Students' performances were recorded and observed to score with rubrics.

https://doi.org/10.33225/jbse/23.22.323

SPS Forms	SPS	Questions
Form 2	Formulating hypotheses	What can you prove about the concepts of expansion-contraction using these materials?
	Inferring	Based on your observations, please write down the effects of heating and cooling on the balloon
	Predicting	What happens to the balloon when it is immersed into hot water? What happens to the balloon if it is immersed in cold water? Please write your prediction.
	Interpreting data	How did heating and cooling influence the balloon? Please respond the question by using the concepts of expansion and contraction.
	Communicating	How can you tell your gained knowledge/experience to your friend?
	Experimenting and observing	* Students' performances were recorded and observed to score with rubrics.
	Classification	In which case does the balloon have the smallest or largest perimeter?
	Controlling variables	What variables did you use in this experiment? a) Which variable affects the balloon's perimeter? Which variable did you change? b) Which variable is affected by heating and cooling? c) Which variables are the same (constant) during the experiment?
Form 3	Formulating hypotheses	What can you prove using these materials?
	Inferring	Based on your observations, please write down your inference about temperature change(s) in the baby food and water.
	Predicting	How can you chill baby food in a bottle?
	Interpreting data	How do the temperatures of baby food and water in a bottle change over time?
	Communicating	How can you tell your gained knowledge/experience to your friend?
	Experimenting, observing and using numbers	* Students' performances were recorded and observed to score with rubrics.

Data Analysis

As seen from Figure 1, the SPSDF were successively administered as a pre and post-test. That is, each form was performed before and after the interventions with the POE worksheets. Furthermore, two researchers observed each SMID's performance and rated their performances using a 4-point rubric (1 = Poor, 2 = Fair, 3 = Good, 4 = Excellent) (see Table S1 in Supplementary Material). The rubric assessed the following SPS: formulating hypothesis, inferring, predicting, classifying, interpreting data, controlling variables, communicating, experimenting and observing. SMID's pre- and post-performances for each SPS were presented to reveal any improvement in their SPS. Also, their scores were initially inserted into Excel and then imported into SPSS 20.0™ to run a non-parametric analysis. That is, the Wilcoxon signed-rank test was used to compare SMID's pre and post-test scores. Further, Cliff's delta value was calculated to portray the extent to which the POE worksheets affect SMID's SPS (Cliff, 1993).

Research Results

As seen from Table 3, the results of Wilcoxon signed rank showed significant differences between SMID's pre and post-test scores of three forms ($z = 2.524$, $p < .05$ for SPS Form 1; $z = 2.527$, $p < .05$ for SPS Forms 2-3) and a total of the SPSDF ($z = 2.533$, $p < .05$) in favour of the post-test ones and fell into positive rank for all of them. As can be seen from Table 1, Cliff's delta (δ) values were found to be 0.796 for SPS Form 1, 0.812 for SPS Form 2, 0.968 for SPS Form 3 and 0.937 for a total of the SPSF. Given the effect size values (0.11—small/weak; 0.28—medium/moderate; 0.43—large/strong) suggested by Vargha and Delaney (2000), Cliff's delta values (see Table 3) of the current research indicated a large effect-size (Macbeth et al., 2011).

https://doi.org/10.33225/jbse/23.22.323

ISSN 1648–3898 /Print/
ISSN 2538–7138 /Online/

Table 3
Results of Wilcoxon Signed Rank and Cliff's Delta Values for the SPSDF

	Post-test Pre-test	*N*	Mean Rank	Sum of ranks	*z*	*p*	Cliff's delta
SPS Form 1	Negative rank	0	.00	.00	-2.524*	.012	0.796
	Positive rank	8	4.50	36.00			
	Equal	0					
SPS Form 2	Negative rank	0	.00	.00	-2.527*	.012	0.812
	Positive rank	8	4.50	36.00			
	Equal	0					
SPS Form 3	Negative rank	0	.00	.00	-2.527*	.012	0.968
	Positive rank	8	4.50	36.00			
	Equal	0					
Total	Negative rank	0	.00	.00	-2.533*	.011	0.937
	Positive rank	8	4.50	36.00			
	Equal	0					

Mean scores of SMID's SPS were also evaluated via the following categories: poor (1.00–1.74), fair (1.75–2.49), good (2.50–3.24) and excellent (3.25–4.00). As seen from Table 4, the 'poor' category contained six SPS for the pre-test and one SPS for the post-test. The number of SPS categorized under the'fair' category was 7 for the pre-test and 3 for the post-test whilst the 'good' category incorporated 5 SPS for the pre-test and 11 SPS for the post-test. Likewise, the number of SPS labelled under the 'excellent' category was 6 for the pre-test and 10 for the post-test.

Table 4
Descriptive Statistics for Pre and Post-SPSDF

SPS Form	Skills	Pre-test				$\bar{x}$	Category	Post-test				$\bar{x}$	Category
		Poor	Fair	Good	Exc.			Poor	Fair	Good	Exc.		
SPS Form 1	Predicting	4	2	2	-	1.75	Fair	-	-	8	-	3.00	Good
	Formulating hypothesis	7		1		1.25	Poor	2		6		2.50	Good
	Interpreting data	-	-	6	2	3.25	Exc.	-	-	5	3	3.375	Exc.
	Interpreting data		2	5	1	2.875	Good			5	3	3375	Exc.
	Inferring	2	-	6	-	2.50	Good	2	-	6	-	2.50	Good
	Communicating	4	-	4	-	2.00	Fair	-	-	7	1	3.125	Good
	Experimenting	-	-	-	8	4.00	Exc.	-	-	-	8	4.00	Exc.
	Observing	-	1	7	-	2.875	Good	-	-	5	3	3.375	Exc.

https://doi.org/10.33225/jbse/23.22.323

SPS Form	Skills	Pre-test				$\bar{x}$	Category	Post-test				$\bar{x}$	Category
		Poor	Fair	Good	Exc.			Poor	Fair	Good	Exc.		
SPS Form 2	Formulating hypothesis	8	-	-	-	1.00	Poor	6	-	2	-	1.50	Poor
	Inferring	5	-	3	-	1.75	Fair	-	-	8	-	3.00	Good
	Predicting	2	5	1	-	1.875	Fair	-	6	2	-	2.25	Fair
	Predicting	-	6	2	-	2.25	Fair	-	6	2	-	2.25	Fair
	Classifying	1	-	1	6	3.50	Exc.	1	-	-	7	3.625	Exc.
	Interpreting data	4	2	1	1	1.875	Fair	-	6	-	2	2.50	Good
	Controlling variables	4	2	1	1	1.875	Fair	-	1	4	3	3.25	Exc.
	Communicating	5	2	1	-	1.50	Poor	-	3	4	1	2.75	Good
	Experimenting	-	-	6	2	3.25	Exc.	-	-	2	6	3.75	Exc.
	Observing	-	-	4	4	3.50	Exc.	-	-	2	6	3.75	Exc.
SPS Form 3	Formulating hypothesis	8	-	-	-	1.00	Poor	4	-	4	-	2.00	Fair
	Predicting	2	1	5	-	2.375	Fair	-	-	8	-	3.00	Good
	Interpreting data	1	2	5	-	2.50	Good	1	-	7	-	2.75	Good
	Inferring	6	-	2	-	1.50	Poor	2	-	3	3	2.875	Good
	Communicating	7	-	1	-	1.25	Poor	2	-	4	2	2.75	Good
	Using numbers	-	-	4	4	3.50	Exc.	-	-	2	6	3.75	Exc.
	Experimenting	-	-	5	3	3.00	Good	-	-	-	8	4.00	Exc.
	Observing	-	-	-	8	4.00	Exc.	-	-	-	8	4.00	Exc.

Exc.: Excellent

Given their engagement with the tasks concentrating on the concepts of "melting and freezing", Ada, Cem and Oya's performances of the 'predicting' skill fell into the 'good' level for pre-and post-test (see Tables S2-3 in Supplementary Material). Ece, Ali, Ada, Nur and Cem's performances of the 'formulating hypothesis' skill were categorized under the 'poor' level for the pre-test and the 'good' level for the post-test. Also, Berk, Ece, Emre, Ali and Ada's performances of the 'interpreting data' skill on the first question fell into the 'good' level for the pre-and the post-test. Moreover, Nur and Oya's performances of the 'interpreting data' skill on the second question were categorized under the 'fair' level for the pre-test and the 'excellent' level for the post-test. Ada, Nur, Cem and Oya's performances of the 'inferring' skill fell into the 'good' level for the pre and post-test. Berk, Ece and Ali's performances of the 'communicating' skill pointed to the 'poor' level for the pre-test and the 'good' one for the post-test. All of their performances of the 'experimenting' skill were categorized under the 'excellent' level for the pre-and post-test. Berk, Ece, Ada and Cem's performances of the 'observing' skill fell into the 'good' level for the pre and post-test.

For the concepts "expansion and contraction" (see Tables S4-5 in Supplementary Material), Berk, Emre, Ada, Cem, Nur, and Oya's pre- and post- performances of the 'formulating hypothesis' skill fell into the 'poor' level. Moreover, Ece and Ali's performances were categorized under the 'poor' level for the pre-test and the 'good' level for the post-test. Similarly, Berk, Ece, Emre, Ali and Nur's performances of the 'inferring' skill were classified under the 'poor' level for the pre-test and the 'good' level for the post-test, while Ada, Cem and Oya's pre- and post- performances fell into the 'good' level. Furthermore, Emre, Ali, Ada and Nur's pre- and post-performances fell into the 'fair' level for the first question of the 'predicting' skill. Interestingly, Berk's pre- and post-test performances were classified under the 'good' and 'fair' levels respectively. Likewise, Emre, Ali, Ada, Nur and Cem's pre and post-performances fell into the 'fair' level

https://doi.org/10.33225/jbse/23.22.323

ISSN 1648–3898 /Print/
ISSN 2538–7138 /Online/

for the second question of the 'predicting' skill. Also, Berk, Ece, Emre, Nur and Oya's pre- and post-performances of the 'inferring and classifying' skills fell into the 'excellent' level. Ece, Emre, Ali and Nur's performances of the 'interpreting data' skills were labelled under the 'poor' level for the pre-test and the 'fair' level for the post-test. Nevertheless, Ece, Emre, Ali and Nur's pre- and post-performances of the 'controlling variables' skill were classified under the 'poor' and 'good' levels respectively. Further, Ali's pre- and post-performances of the 'communicating' skill fell into the 'fair' level, whereas Ali and Oya's pre- and post-performances of the 'experimenting and observing' skills fell into the 'excellent' level. Similarly, Ece, and Cem's pre- and post-performances of the 'observing' skill were classified under the 'excellent' level.

For the concept of "heat exchange" (see Tables S6-7 at Supplementary Material), Berk, Ada, Nur and Cem's pre- and post-performances of the 'formulating hypothesis' skill fell into the 'poor' level, whilst Ali, Ada, Nur, Cem and Oya's pre- and post-performances of the 'predicting' skill were labelled under the 'good' level. Furthermore, Ali's pre- and post-performances of the 'interpreting' skill were classified under the 'fair' and 'good' levels respectively. Berk and Cem's pre- and post-performances of the 'inferring' skill were categorized under the 'poor' and 'excellent' levels respectively, whilst Berk and Ece's pre- and post-performances of the 'communicating' skill fell into the 'poor' level. Nur and Cem's pre- and post-performances of the 'using numbers' skill revealed the 'good' and 'excellent' levels respectively. Similarly, Ali, Cem and Oya's pre and post-performances of the 'experimenting' skill fell into the 'excellent' level, while all of the pre-and post- performances of the 'observing' skill were categorized under the 'excellent' level.

Discussion

A strong/large effect size means that the POE worksheets are effective in developing SMID's SPS of the "matter and its nature" subject (see Table 1). Given the mean scores of pre-and post-SPSDF, the POE worksheets have resulted in positive improvements (see Tables 3-4), except for 'no change' in the 'experimenting, predicting and observing' skills. Further, some of them showed a categorical change (e.g., from the 'poor' level to the 'good' one for the 'formulating hypothesis' skill). This may be explained by Vygotsky's zone proximal development. That is, the POE worksheets seem to have reduced the distance(s) between the actual and potential development levels of SPS. In a similar vein, since zone proximal development level is varied for each SMID, the teaching intervention may have caused different learning outcomes and/or achievement performances. In brief, the POE worksheets accompanied by hands-on experiments, QR codes, buzz-22, snowball and learning gallery not only enhanced SMID's learning abilities but also afforded them to develop their SPS.

The fact that most of the students somewhat developed the 'predicting and interpreting data' skills may result from hands-on and minds-on activities in the teaching intervention. However, a short-term treatment and/or the characteristics of these skills that require them to associate their current experiences/knowledge with previous ones may have resulted in a limited growth in these skills. Unfortunately, the fact that SMID generally has difficulties retaining relevant knowledge in short and long-term memory and retrieving related one from long-term memory seems to have restricted any improvement in the 'predicting and interpreting data' skills (Friend, 2006; Lifshitz et al., 2011a,b; Werts et al., 2007).

Positive changes in the 'formulating hypothesis, inferring and controlling variables' skills may stem from the POE worksheets enriched with active learning techniques (e.g., Buzz 22). That is, the POE worksheets guided SMID to formulate hypothesis, infer from the results and control variables. However, the fact that the teaching intervention did not make a linear effect to SMID may come from their traits (e.g., readiness, level of learning disability and a need for understandable words vis-à-vis scientific jargon) (Şenel-Çoruhlu et al., 2022). For example; the POE worksheet asked them to focus on what they were looking for and what factor affected the balloon's perimeter instead of the terms "dependent and independent variables". Thus, such clear and understandable expressions may have facilitated their ability to control variables.

Even though SMID has deficiencies in clearly expressing their feelings and ideas, the POE worksheets have positively improved their communication skills that support scientific thinking and social interactions (Ercan, 2004; Şenel-Çoruhlu et al., 2022). In other words, the POE worksheets seem to have strengthened their communication skills (Davies & Ball, 1978) by encouraging them to ask questions, initiate discussions and express their views (Ege, 2006). For instance, SMID initially conducted the experiments and addressed their views via buzz 22 and snowball techniques. Also, they watched the QR-coded videos to repeat and support their gained knowledge. Such a process may have triggered their communication skills and learning performance (Er-Nas et al., 2022; Mastropieri et al., 1999).

The fact that the POE worksheets guided SMID to learn about how to observe and conduct the experiments may have facilitated their observational and experimental skills. Furthermore, the fact that their pre- and post-performances

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of the 'classifying' skill fell into the 'excellent' level may stem from their prior experiences (Saban, 2015). That is, this skill is fundamentally taught in early schooling years. Also, the fact that the POE worksheets engaged them in classifying the data may have empowered their classification skill.

Conclusions and Implications

In the light of the results, the POE worksheets enriched with active learning techniques (e.g., hands-on experiments, QR codes, buzz-22, snowball and learning gallery) have enabled SMID to develop their SPS. Because the teaching intervention had resulted in various learning outcomes for SMID, future studies should carefully align their teaching interventions with the nature of SMID and Vygotsky's zone proximal development. Since the current research includes promising results for science education and special education, future research should prepare similar guide materials for other science topics and share them with stakeholders. Because each SMID has her/his unique learning needs, further research should focus on training science teachers and special education teachers to meet their learning needs in practicum. Also, given the students' interest in their personalized avatars and QR-coded videos, future studies may concentrate on how to integrate digital sensors and materials into inclusive science education. Even though the current research embedded varied learning techniques (hands-on experiments, QR codes, buzz-22, snowball and learning gallery) within the POE worksheets, it viewed the POE worksheets as a driving factor. Thus, it claimed that any improvement belonged to the POE worksheets. Someone may view it as a limitation of the research. For this reason, future comparative research should unveil how the POE worksheets with/without active learning techniques impact SMID's SPS.

Acknowledgements

This research was funded by TUBITAK (Grant number: 118R017). It also acted as a dissemination outcome of the project where the last author prepared her master's thesis under the supervision of the third author. The authors would like to thank the entire project team and TUBITAK for their kind help. Also, an earlier version of "the secret of change in chocolate" worksheet was presented at the International Science, Mathematics, Entrepreneurship and Technology Education Congress in İzmir/TÜRKİYE (April 12-14, 2019).

Supplementary Material

Please visit the link https://www.researchgate.net/publication/366200424_SM_JBSE for related figures and tables.

Declaration of Interest

The authors declare no competing interest.

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Received: *November 12, 2022* Revised: *February 25, 2023* Accepted: *March 15, 2023*

Cite as: Şenel Çoruhlu, T., Çalık, M., Er Nas, S., & Bilgin, B. (2023). Improving science process skills of students with mild intellectual disabilities. *Journal of Baltic Science Education*, *22*(2), 323-336. https://doi.org/10.33225/jbse/23.22.323

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