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INSTRUMENT DEVELOPMENT TO EXAMINE LENGTH-MEASUREMENT ABILITIES AND SPATIAL-SENSE AMONG FIVE-YEAR-OLD CHILDREN

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Abstract

Length is a dimension in space used to measure the distance between two points. Developing skills related to spatial sense at an early age, including understanding the concept of length and its measurement, promotes more complex understanding in the context of location, direction and movement in space. The kindergarten mathematics curriculum emphasizes the importance of advancing length-measurement skills in daily life using a variety of accepted means of measurement in real-life kindergarten situations. This article presents a research study that accompanied development of an instrument aimed at identifying length measurement and spatial sense abilities among 5-year-old children. The instrument identifies length measurement capabilities through direct comparison, through a mediator, and through the use of units of measurement employing a variety of means. Measurement by various means allows for mental rotation, visualization and representation as well as exploration to develop spatial sense. Development of the instrument is based on the requirements of the mathematics curriculum for kindergarten children, as well as on theoretical and research knowledge. The instrument includes 32 questions, 22 of which test capabilities in length measurement, and the remainder capabilities in spatial sense. The children are asked to act in a variety of situations. The article presents examples of questions as well as findings regarding the reliability of the assessment and the validity of the instrument. It is important that the instrument be incorporated as part of the teaching of length measurement in kindergarten as it is a means of assessing children's knowledge and spatial sense.

Keywords: Abilities, length measurement, preschoolers, spatial sense

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1. Introduction

Kindergarten in Israel serves as an educational learning framework aimed at advancing and encouraging the child's development. The educational learning activities practised in kindergarten are multidisciplinary and include physical and motor development, inculcation of emotional, social and moral values, development of cognitive and learning skills, consolidation of intellectual attitudes, and incorporation of content, knowledge and cultural resources (Ministry of Education, 2010).

In many cases the teaching of children is characterized by the fact that they are learning all the time and everywhere (Johnson et al., 2019), through both random and organized experiences, with each experience contributing to the process of development. Balanced learning and development in a variety of areas necessitate focused educational investment on the part of the kindergarten teacher, who has been specially trained for this purpose (Ministry of Education, 2010). The teacher's approach must be differential: her activities must be structured with a view to the child's abilities, his fields of interest, and his attentiveness during the activity. The teacher mediates between the child and his storehouse of stimuli, both randomly and intentionally.

This article presents an instrument that could assist the kindergarten teacher in planning and constructing geometric activities suited to the child based on his abilities. The instrument enables the teacher to assess the child's abilities in terms of length measurement and spatial sense. It can be used both to assess abilities and plan instruction for the children.

Length is a dimension in space that is used to measure the distance between two points. Development of skills relating to spatial sense in pre-school children, including understanding of the concept of length and its measurement, promotes more complex understanding with regard to location, direction and movement in space. The kindergarten mathematics curriculum thus emphasizes the high importance of developing a spatial sense, manifested in the ability to understand and use verbal descriptions and visual representations, and in fostering skills relating to length measurement in daily life, using a variety of accepted means of measurement in real-life situations in the kindergarten (Ministry of Education, 2010).

Researchers claim that exposing children to and engaging them in diverse activities in the fields of mathematics and the sciences, including geometry, will advance development of their abilities speedily and optimally (Smith et al., 2015).

The following section presents the principal concepts that served as a basis for development of the instrument.

2. Problem Statement

2.1. Pre-School Geometry

Geometry is important for an understanding of the world around us and for proper orientation within it. The child develops and operates in an environment consisting of objects and shapes, and his familiarization with them helps him to acquire a spatial sense.

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Young children encounter a variety of geometrical representations on a daily basis in the environment to which they are exposed – from the first toys as infants, in the children's den, in the bathtub, indoors and outdoors, to games that are geared to cultivating knowledge in the field.

Children employ mathematical thinking quite naturally when comparing, quantifying and exploring spaces and shapes in the world around them (Kinzer et al., 2016). These activities are performed daily in a variety of situations in the kindergarten. In the wider context, geometry and spatial sense are important not only in their own right, but also in the contribution they make to mathematical perceptions and skills (Arcavi, 2003).

2.2. Development of Geometric Cognition in Pre-Schoolers

Children entering the educational system arrive with knowledge of the world gained through their experiences. They bring with them non-formal intuitions regarding spatial perception and spatial orientation. These concepts have been developed in them as a result of interconnections experienced in various cultural contexts, such as the mobile over the baby crib, children's books and puzzles (Markowitz, 2018). Researchers agree that infants do not from the moment of birth perceive the world as a chaotic mix of moving, changing stimuli. They use their sensory capacity in an organized manner: they scan their environment and focus on outlines, following which they begin to observe the inner lines of objects (DeHart et al., 2000).

Research on the human brain has progressed considerably in recent times, based on which we learn (Markowitz, 2018) that:

1. The pre-schooler's brain undergoes substantial development.
2. The experiences and learning to which pre-schoolers are exposed affect their brain structure and organization.
3. The pre-schooler's brain develops to a greater extent as a result of engaging in complex activities than in the learning of simple skills.

The brain is nourished through the senses, creating perception, which comprises a process of classifying and interpreting stimuli received by the senses and making the environment a meaningful place (Clements et al., 2018).

Pre-schoolers in kindergarten have access to an environment rich in stimuli, without their classifying them according to their individual development stage. Children from different backgrounds and different experiences get together for activities involving building and game playing based on interaction between themselves, and between them and an adult, contributing to wider learning and experimentation. At the same time, the child's maturity must be taken into account, in terms of his learning potential (Vygotsky, 1978), personal development capacity (Piaget, 1952) and geometric cognition development (van Hiele, 1999).

van Hiele (1999) describes the development of geometric cognition by progression along five hierarchical levels (Figure 1). This takes place in stages, and advancement from one level to a higher one leads to formal geometric cognition. Pre-schoolers are at one of the two initial levels of geometric cognition:

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1.Recognition: the child looks at the shape as a whole and not as the sum of its component parts. Perception of shape is global. The child's conclusions at this level are confined to naming and classification according to overall shape. The child is not yet familiar with the properties of the shapes.

2.Analysis: the child is familiar with the shapes according to their properties but is still unable to understand that one property derives from another. The child's conclusions at this level are no more than informal analysis of the shape's properties.

3.Order: level of abstraction, formation of logical connections between the geometric properties.

4.Deduction: development of the ability to use proofs and axioms.

5.Rigour: at this level the child understands the formal aspect of geometry.

Clements and Sarama (2000) claim that it is possible to refer to three levels of geometric understanding at pre-school age, such that their pre-recognition and visual levels lie within the first van Hiele level, while their third level corresponds to the second van Hiele level (Figure 2):

1.Pre-recognition level: the child internalizes shapes but is not able to distinguish between many shapes.

2.Visual level: the child identifies shapes according to their overall appearance or according to one aspect of the shape.

3.Analysis: the child identifies shapes and is able to characterize them according to their properties.

Advancement along the cognitive levels depends to a great extent on education and learning. Much importance is attached to the kindergarten teacher's familiarity with the child's cognitive level as this knowledge can guide her in choosing appropriate learning opportunities for the child.

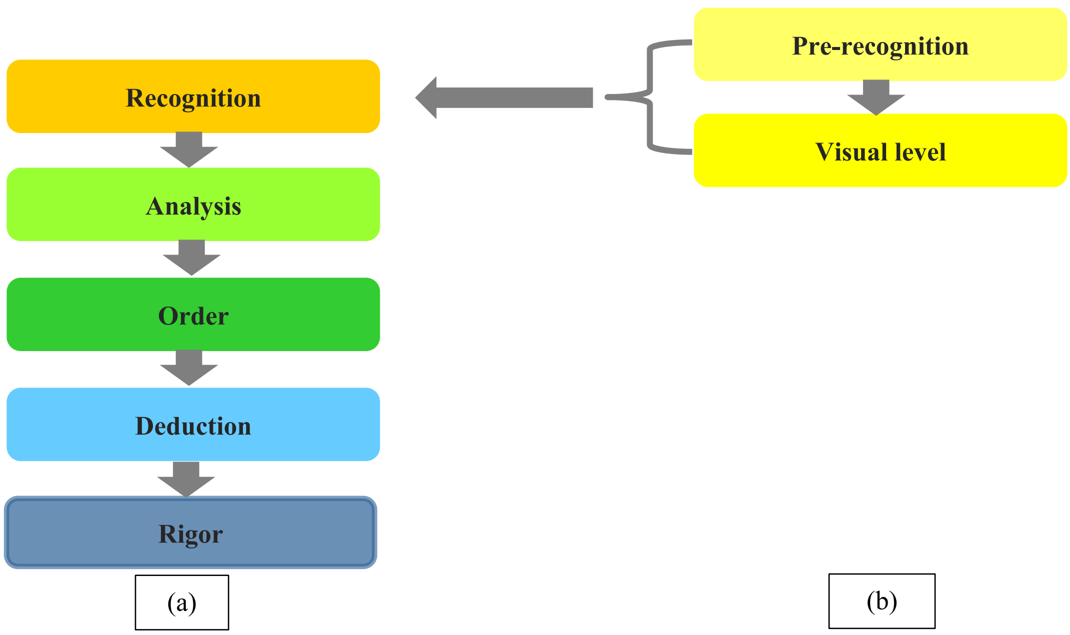

Figure 1. (a) Geometric cognitive level (van Hiele, 1999), (b) Geometric cognitive (Clements & Sarama, 2000) level

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2.3. Measurement of Length

We are engaged on a daily basis in performing measurements in various fields. Measurements can be made in a relative manner by comparing sizes, either by direct comparison or through a mediator. The answer obtained is a relative one (big, small or equal).

Measurements can also be made using units of measurement. When measuring this way one checks to see how many times a certain unit of measurement goes into the object being measured. The unit of measurement can be arbitrary – e.g. a regular walking pace, a popsicle stick – or an accepted one, e.g. a ruler. When measurements are carried out using units of measurement (arbitrary or accepted) the answer obtained is a number indicating the ratio of the measured object to the unit of measurement (Clements & Sarama, 2014).

The focus in kindergarten is on length measurement (Ministry of Education, 2010). The stages the child passes in acquiring the necessary skills are:

Direct comparison: two objects are compared relative to the size of a common gauge (length, weight, etc.) without the use of a mediator.

Comparison with the help of a mediator is performed by comparing two objects with the help of a third object (e.g. a string, a stick) mediating between the two.

When two objects situated at a distance from each other are compared, the help of a mediator can be sought. Generally this is done as follows: one of the objects is compared to the mediator, after which the mediator is compared to the other object. Conclusions are drawn accordingly. It is important to discuss the choice of a suitable mediator with the child to enable him to make an effective, easy comparison (Zacharos & Kassara, 2012).

Measurement using arbitrary measuring aids is performed as follows: a check is made to see how many times the arbitrary unit of measurement goes into the object being measured. The answer regarding the length of the object depends on the unit of measurement being used (a human foot, popsicle stick, cubes).

1. In measuring length, care should be taken to ensure that the units of measurement are placed adjacent to each other with no gaps in between. It is also important to place the unit of measurement at the starting point of the measured object. The unit of measurement should be selected such that it will be suited to the measured object as well as to the child's counting capabilities.
2. When two objects are measured and compared, the same unit of measurement is generally used.
3. When the unit of measurement does not go into the measured object a whole number of times, the length can be described as slightly more than … or slightly less than …
4. If the same object is measured using different units of measurement, two different answers are obtained, both of which will be correct according to the unit of measurement used.
5. When we measure the same object using different units of measurement, the smaller the unit of measurement, the greater will be the number obtained (Clements, 1999; Lehrer, 2003).

Measurement using accepted measuring aids. The use of accepted units of measurement ensures receipt of a uniform result with respect to the measured object. It is recommended that children familiarize themselves with these measuring aids, e.g. a ruler, a measuring tape. It is important to demonstrate to children the use of accepted measuring aids in real-life situations in the kindergarten (Ministry of Education, 2010).

2.4. Spatial Sense

Spatial sense refers to the ability to identify, comprehend and process information regarding the shapes and locations of stimuli in space (Uttal et al., 2013). Okamoto et al. (2015) identify four components of spatial skills:

1. Visualization and representation: the ability to see relationships between fixed objects in real life, and in graphic representations, e.g. putting together and building a picture based on geometric hints; building models of spaces in the kindergarten or of the playground, together with toys such as dolls' furniture or blocks; creating simple maps.
2. Navigation: the child's ability to discern perspective and self-motion; the ability to see changing relationships between objects in motion; the use of prepositions such as next to, near and between; starting to use relational concepts, such as left and right.
3. Mental rotation and transformation of shapes and static and dynamic objects, e.g. completing a jigsaw puzzle or a picture using pieces; building a model from blocks.
4. Identification, disassembly and assembly of geometric shapes, e.g. identification and classification of a variety of shapes through construction of polygons from different shapes regardless of size or position.

Activities in kindergarten provide a natural opportunity for advancing geometric cognition. Familiarization with concepts and their proper use can serve as a foundation for more widespread, confident use in the future. Regrettably, the tendency is often to disregard or underestimate activities relating to geometry and spatial cognition with pre-schoolers (Clements & Sarama, 2011). Thus, giving geometric aspects the attention they merit will provide the kindergarten teacher with an opportunity to incorporate concepts and skills for children in a variety of ways.

This article presents a process for constructing a valid diagnostic instrument for assessing capabilities relating to length measurement and spatial sense. The instrument focuses on an examination of length-related skills on different levels using diverse means, as well as for examining spatial sense according to different elements. The goal is to build a foundation that will allow the kindergarten teacher to determine the pre-schooler's capability level, serving as a starting point for constructing a program for development-oriented learning that will answer the child's needs and satisfy his spheres of interest.

3. Research Questions

The research question is: How does one assess the geometric ability of 5-year-old children?

As stated, the instrument proposed herein measures the geometric capabilities of 5-year-old children in terms of length measurement and spatial sense. A number of key points must be taken into consideration in constructing the instrument for young children, as follows:

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1. Geometric concepts tested by the instrument. Consideration must be given to the manner in which these concepts develop in pre-schoolers. What in the staged development of these concepts is relevant to this age group?
2. Compatibility with the child's level of maturity, i.e. his learning potential, his personal development, and the level of development of geometric cognition at his existing stage.
3. Suitability of the instrument for use with young children. Consideration must be given to the type of interview suited to children at this age, to an appropriate vocabulary, to the duration of the interview taking into account the child's attention span, and to the visual aids used to illustrate the concept.
4. The educational figure conducting the interview. This should be someone who has been trained to work with pre-schoolers, who upholds professional ethics and the need to safeguard the participating children from harm.
5. Interpretation of the children's answers given during the interview. Construction of a sensitive scale that takes into account the child's specific behaviour in the field under examination. These behaviours could in time assist in building a program of instruction that will be suited to the child.

4. Purpose of the Study

The purpose of the study is to develop an instrument for geometric diagnosis that will examine capabilities with respect to length measurement and spatial sense in 5-year-old kindergarten children. The study will also examine the reliability and validity of the instrument.

The instrument can serve as a work tool for educationists and researchers as well. Education personnel can use it to assess abilities and plan instruction programs for children. Researchers can use it for academic studies to investigate children's capabilities.

5. Research Methods

5.1. The Sample

The research described in this article made use of a convenience sample comprising 29 children. Twelve children participated in the first pilot study, and another 17 in the second pilot study. The average age of the children at the time of the first pilot was 5 years and 2 months (SD=0.37), and their average age at the time of the second pilot was 5 years and 3 months (SD=0.36). The ages in the first pilot ranged from 4 years and 10 months to 5 years and 10 months. The ages in the second pilot ranged from 4 years and 9 months to 5 years and 10 months. All the children received a regular education in a regular state kindergarten. The kindergartens selected for the convenience sample were situated in a large neighbourhood in a city in southern Israel. The socioeconomic status of most of the population in this neighbourhood was average to high average.

The above data serve for background information only and no use was made of them in the study analysis.

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5.2. Development of the Instrument

The instrument was developed in accordance with the requirements of the kindergarten mathematics curriculum (Ministry of Education, 2010), as well as on the basis of theoretical and research knowledge regarding length measurement and spatial sense. The instrument includes tasks involving measurement of length using different means and strategies (direct comparison, use of a mediator, use of a unit of measurement), as well as tasks in the way of spatial sense combining abilities based on spatial skills (visualization and representation, navigation, mental rotation and transformation, identification, disassembly and assembly of geometrical shapes).

5.3. Description of the Instrument

The instrument described in this article is intended for use with pre-schoolers. Hence, an instrument was developed that allows a "cognitive clinical interview" (Ginsburg, 2012) and is special in terms of its informal makeup and the greater freedom it allows vis-à-vis certain tests. This kind of interview enables understanding of children's cognitive abilities to a very great extent while providing, in parallel, a basis for planning instruction that will be appropriate for the children (Ginsburg, 2009). This constitutes in practice assessment for the purpose of instruction, which progresses with performance and allows children's instruction to be enhanced, especially for those with learning difficulties. During the course of the interview, the interviewer, bound ethically to act respectfully towards the child, attempts to establish a sense of trust in the child in order for him to agree to reveal his thought processes. The interviewer uses slightly different wording in each case and sets tasks that are suited to the individual child, based at times on a spontaneous response to the situation and the child. This kind of interview sheds light on the child's world view. It exposes the child's thoughts and deliberations, while possibly even hastening his cognitive development. The control afforded the child in the course of the interview enables him to take a look at himself and try to understand how he has arrived at an answer – a process referred to as metacognition.

The instrument includes 32 questions according to the following breakdown: a part that examines abilities with respect to length measurement, including 22 questions, and a part that examines abilities in the realm of spatial sense, including 10 questions.

Some of the questions involve a number of steps or repeated trials using identical or different means. For example, the child is presented with a certain means, and a question is asked inquiring about length or spatial sense. Following receipt of a correct answer, accessories are presented and an additional task is defined that further tests the required capability. The child's responses are recorded and charted on a scale ranging from 0 (did not answer, answered incorrectly, or answered correctly after many attempts) to 4 (correct answer, at times also necessitating explanation). All the questions in the instrument require the use of illustrative means, providing something that the children can work with. They can think about the activities they carry out in connection with the concepts the educator has tried to establish (English & Halford, 2012). Young children must be exposed to concrete experiences in order to understand mathematics (Cai, 1998), although it is still important to be aware of the myriad interpretations of such experiences (English & Halford, 2012).

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5.4. Performing the Interview

The interview was conducted by the researcher alone in a quiet corner of the kindergarten, each time with a different child. It consisted of a single session in which the researcher presented a series of questions with the help of aids. During the course of the interview the child's answers were recorded verbatim in a special table prepared for this purpose.

5.5. Analysis of Results

Following receipt of the results a series of statistical tests were performed in order to establish the instrument's reliability and validity:

1. Examination of the instrument's internal reliability (calculation of Cronbach's alpha).
2. Examination of the distribution of length measurement and spatial sense results.
3. Examination of the relationship between the child's age and his abilities with respect to length measurement and spatial sense using Pearson's correlation.

6. Findings

6.1. Reliability

The instrument's reliability is gauged by the consistency in obtaining "identical" results, taking into account the fact that environmental conditions are unchanging. An index is judged to be valid if it reflects the true values that it is intended to measure. One of the ways to measure an instrument's reliability is by calculating the Cronbach alpha coefficient, which defines the internal reliability of the instrument by examining the internal correlation between the component items.

The reliability for length measurement in the first pilot (N=12) and the second pilot (N=17) is presented in Tables 1 and 2, respectively.

Table 1. Reliability of Instrument Items for Length Measurement in the First Pilot

Item number	Corrected item – total correlation	Cronbach's alpha if item deleted
Question 1	0.30	0.64
Question 2	-0.04	0.67
Question 3	0.01	0.66
Question 4	0.31	0.65
Question 5	0.19	0.66
Question 6	0.19	0.66
Question 7	0.24	0.65
Question 8	0.06	0.67
Question 9	0.50	0.61
Question 10	0.43	0.63
Question 11	0.34	0.64
Question 12	0.31	0.65
Question 13	0.14	0.66
Question 14	0.00	0.66
Question 15	0.21	0.65

Question 16	-0.18	0.67
Question 17	0.08	0.66
Question 18	0.20	0.65
Question 19	0.57	0.60

It may be seen from Table 1 that the reliability of the instrument's length measurement is medium to high (α=0.66), with a number of items that were found to be inconsistent for a research instrument. With a view to improving the reliability, but at the same time not reducing the number of items relating to length measurement, four items were removed from the instrument which were found to have a low correlation with the other items in the instrument. Subsequently, in the second pilot, seven additional items were incorporated, such that the number of items for length measurement in the second pilot was 22.

Table 2. Reliability of Instrument Items for Length Measurement in the Second Pilot

Item number	Corrected item – total correlation	Cronbach's alpha if item deleted
Question 1	0.42	0.73
Question 2	0.18	0.76
Question 3	0.13	0.75
Question 4	0.43	0.74
Question 5	0.31	0.75
Question 6	0.31	0.75
Question 7	0.36	0.74
Question 8	0.18	0.76
Question 9	0.62	0.7
Question 10	0.55	0.72
Question 11	0.46	0.73
Question 12	0.43	0.74
Question 13	0.26	0.75
Question 14	0.12	0.75
Question 15	0.33	0.74
Question 16	0.13	0.76
Question 17	0.2	0.75
Question 18	0.32	0.74
Question 19	0.69	0.69
Question 20	0.39	0.74
Question 21	0.4	0.74
Question 22	0.28	0.76

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Following the removal of items and addition of new ones, the instrument's internal reliability for length measurement in the second pilot was found to be high and satisfactory (α=0.75), enabling the use of the instrument for further research.

The research instrument referring to spatial sense included six items in the first pilot, as shown in Table 3.

Table 3. Reliability of Instrument Items for Spatial Sense in the First Pilot

Item number	Corrected item – total correlation	Cronbach's alpha if item deleted
Question 1	0.27	0.72
Question 2	0.40	0.70
Question 3	0.32	0.71
Question 4	0.39	0.70
Question 5	0.38	0.70
Question 6	0.42	0.70

The instrument's reliability with respect to spatial sense was found to be medium to high (α=0.72). Although this was deemed to be satisfactory, an adjustment was made in the scale for the instrument items such that, like the length measurement instrument, the score for each item in the spatial sense instrument would range from 0 to 4. Moreover, four questions were added with a view to covering wider content related to spatial sense. Thus, included in the second pilot were a total of 10 spatial sense items, as presented in Table 4.

Table 4. Reliability of Instrument Items for Spatial Sense in the Second Pilot

Item number	Corrected item – total correlation	Cronbach's alpha if item deleted
Question 1	0.39	0.80
Question 2	0.52	0.79
Question 3	0.44	0.80
Question 4	0.51	0.79
Question 5	0.50	0.77
Question 6	0.54	0.78
Question 7	0.54	0.78
Question 8	0.60	0.77
Question 9	0.42	0.79
Question 10	0.64	0.75

As shown in Table 4, the internal reliability of the research instrument following adjustment of the scale and addition of the four items was found to be high (α=0.81).

In summation, the internal reliability of both research instruments (length measurement and spatial sense) following removal of items found to be in poor correlation with the other items in the instrument,

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addition of new items and adjustment of the scale, was found to be high. The Cronbach alpha correlation in the second pilot for length measurement was 0.75 and for spatial sense 0.81, allowing the instrument to be used for further research as well.

6.2. Examination of Distributions

Table 5 presents the means, standard deviations, and minimum and maximum values for the instrument in the second pilot

Table 5. Means, Standard Deviations, Minimum and Maximum Values and Significance of High Scores in Each Research Instrument

Variable	M	SD	Max	Min	Significance of high score
Length measurement	1.98	0.49	3.15	0.82	High length measurement ability
Spatial sense	1.94	0.63	3.44	0.54	High spatial sense ability

Table 5 shows that the mean values of the children who participated in the research were very close to the middle of the research instrument scale, ranging from 0 to 4, in the second pilot. The standard deviation in both the variables was less than 1. It may therefore be stated that the children's distribution was relatively homogeneous, around the middle score in the instrument.

6.3. Validity

6.3.1. Content Validity

The instrument used in the research was transmitted to three specialists in the field of mathematics, one of whom specialized in mathematics for pre-schoolers. These specialists assessed the suitability of the instrument for the age group (5-year-old pre-schoolers) and the manner in which the tasks were constructed. Their assessments attested to the fact that the instrument encompasses the entire content relating to length measurement and spatial sense for 5-year-olds. Their approval thus confers on the instrument both face validity and content validity.

6.3.2. Convergent Validity

In order to examine the convergent validity, Pearson correlations between the children's age and both length measurement and spatial sense were carried out. The results are presented in Table 6.

Table 6. Pearson Correlations between Research Variables and Children's Age (in months)

	Length measurement	Spatial sense	Age
Length measurement	-	.58**	.31**
Spatial sense	-	-	.35**
Age			

**p<.01

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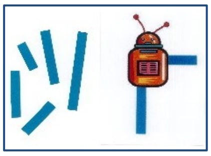
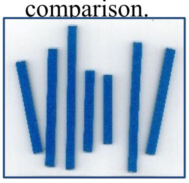
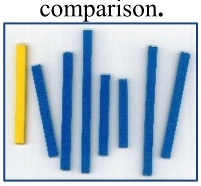
As seen in Table 6, significant positive correlations of medium strength were found between the variables, attesting to the high convergent validity of the correlations in accordance with cognitive and social development theories (Piaget, 1952; van Hiele, 1999; Vygotsky, 1978). According to these theories, abilities with respect to length measurement and spatial sense are development capabilities that undergo enhancement with age, and therefore the existence of significant correlations between the research variables and children's age attests to high convergent validity for the research instrument.

7. Findings

As stated, an instrument was constructed to test the abilities of 5-year-old children in two key areas: length measurement and spatial sense. The instrument includes 32 questions.

Examples of questions identifying the children's capabilities in length measurement using various means and strategies are presented in Tables 7 and 8. And questions identifying their capabilities in spatial sense are presented in Tables 9 and 10.

Table 7. Questions for Identification of Length Measurement Abilities

Question No.	Geometrical goal	Question and description	The child's expected answer	
8	Length measurement through direct comparison Choice out of a variety	I will place a card in front of the child on which is drawn a robot with one hand and one leg. I will put five strips of the same colour, of different lengths, and will ask him to look for the missing hand and foot in that length.	The child will make a direct comparison 	A card on which is drawn a robot with one hand and one leg. Five strips of the same colour, of different lengths Adapted from: Hershkovitz (2002). "Trails" for First Grade, Part A. CET (The Center for Educational Technology). [Hebrew]
9	Ordering through direct comparison	I will place in front of the child 7 strips of the same colour, of different lengths. I will ask him to arrange the strips in a row, from the shortest to the longest.	The child will arrange the strips using direct comparison. 	Strips of the same colour, of different lengths. Piaget (1952). *The Child's Conception of Number.* London: Routledge & Kegan Paul.
10	Ordering through direct comparison	If the child has succeeded in arranging the sticks in the correct sequence from the shortest to the longest, I will give him another strip of intermediate length to be placed in the right place in the series. What did you do to find the location?	The child will place the strip in the right place using direct comparison. 	One strip of a different colour Piaget (1952). *The Child's Conception of Number.* London: Routledge & Kegan Paul.

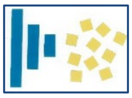
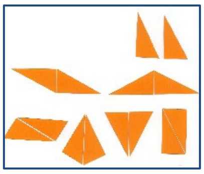
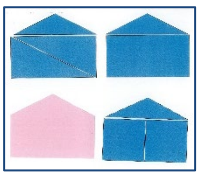
20	Comparison using a unit of measurement The number of units is large and sufficient for measurement	I will show the child three blue strips, 2, 4 and 7 inches long, and 10 yellow strips, one inch long. I will ask the child which of the blue strips is exactly equal to 4 yellow strips in length.	The child will use the units correctly to decide which of the strips is equivalent to 4 yellow units. 	3 blue strips in lengths of 2, 4, 7 inches, 10 yellow strips one inch long. Szilágyi et al. (2013). Young children's understandings of length measurement: Evaluating a learning trajectory. *Journal for Research in Mathematics Education*, *44*(3), 581-620.

Table 8. Scaled Answers to Questions Testing Length Measurement

Question No.	4 points	3 points	2 points	One point	No points
8	2 correct strips 2 attempts	2 correct strips 3 attempts	2 correct strips 4 attempts	At least one correct answer or 2 correct strips, 5 or more attempts	2 incorrect answers
9	Arranged 7 strips correctly	Arranged 5-6 strips correctly	Arranged 3-4 strips correctly	Arranged 2 strips correctly	Did not succeed in arranging the strips at all
10	Correct answer after 1-2 attempts	Correct answer after 3-4 attempts	Correct answer after 5-6 attempts	Correct answer after 7 or more attempts	Did not find the correct place for the strip
20	Correct answer without measurement	Correct answer following measurement	Correct answer following correction	Chooses the longest or shortest strip	Different activity unrelated to the strips

Table 9. Questions for Identification of Spatial Skills

Question number	Geometric goal	Question and description	The child's expected answer	Props and source
1	Disassembly and assembly identification Mental rotation and transformation	I will give the child a few right-angled scalene triangles. I will ask him each time to connect two triangles in different ways. Just along a side.	The child will be able to create at least 3 different polygons. 	Multiple right-angled triangles and different sides. Adapted from: Ministry of Education. (2010). Israel National Mathematics Preschool Curriculum. [Hebrew]
5	Disassembly and assembly identification Mental rotation and transformation Visualization and	The child will be asked to tile the house in the parts shown in front of him. I tell him he does not have to use all the parts. After he finishes, I will ask: Can you use other parts to fill the shape?	The child will be able to tile the house in different ways. 	A card with a house painted on it, various polygons for flooring. Shaeib and Tabach (2014). How Can the Level of Geometric Thinking In Early Childhood be Advanced? Demonstration of Case Study from an Extended Research.

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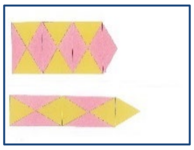
	representation			"Strong Number 2000", 25, 14-25. [Hebrew]
10	Disassembly and assembly identification Mental rotation and transformation Visualization and representation Navigation	I will build for the child's eyes a repeating pattern composed of triangles. I say: If you have some such triangles can you make these repeating patterns? How did you know where to place the triangles?	The child will be able to continue the repeating pattern. 	Triangles in two colours and different sizes (one an equilateral triangle and the other an isosceles obtuse triangle) Adapted from: https://nrich.maths.org Faculty of Education, University of Cambridge.

Table 10. Scaled Answers to Questions Testing Spatial Sense

Question No.	4 points	3 points	2 points	One point	No points
1	5 correct answers	4 correct answers	3 correct answers	Less than 3 correct answers	Did not connect two triangles along the side and did not form a polygon
5	3 correct answers		2 correct answers	One correct answer	Did not succeed in building
10	Continues the two models accurately	Continues one model accurately and builds the second model on top of the existing model	Builds one model accurately and the second model incorrectly, or builds both models accurately on top of the existing model	Builds one of the models on the existing model and the second model incorrectly	Builds both models incorrectly

8. Conclusion

The aim of the article was to assess the geometric abilities of 5-year-old children using a reliable and valid instrument. The proposed instrument is adapted for use by kindergarten teachers and for researchers coming in contact with pre-schoolers. The instrument tests the geometric abilities of 5-year-olds in two key areas: length measurement and spatial sense. It includes 32 tasks in the above areas.

Analysis of the research findings shows that the instrument's reliability and validity indices are high. It was found that the internal reliability is high, i.e. its items (tasks) are consistent, allowing the abilities of pre-schoolers in length measurement to be tested using a variety of aids and strategies, as well as the children's abilities with respect to spatial sense, based on a range of spatial skills. It was also found that the instrument has face and content validity, in addition to convergent validity based on the correlation between the children's age and their abilities with respect to length measurement and spatial sense. The findings show that it is possible, indeed important, to use this instrument in order to identify

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abilities in the realm of length measurement and spatial sense among 5-year-olds. Further, the instrument, designed for use as a clinical interview, can be used by the kindergarten teacher as a development-oriented program to advance children from their existing level (Ginsburg, 2012).

The instrument has been adapted for use with 5-year-old children. It takes into account the child's maturity, his ability with respect to personal development, and the level of his geometric cognition development. The instrument includes an appropriate vocabulary. The duration of the activity takes into account the child's attention span at this age. The visual aids are a good illustration of the concepts being tested.

The present research has a number of limitations. Firstly, the instrument was tested on a relatively small number of children. It is recommended to increase the number of participants and to check the extent to which the instrument is reliable with other cultures, as well as its sensitivity vis-à-vis other age groups. Secondly, the instrument comprises a mix of many illustrative aids; though adapted to the child's age and providing something with which the child can work, it constitutes a difficulty for the kindergarten teacher in preparing the various means involved. Thus, the instrument could find particular use in cases where the kindergarten teacher is of two minds regarding the abilities of a specific child or group of children.

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