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Evaluation of Geography Instructor-Candidate's Spatial Thinking Ability through Spatially Designed Field-Course

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***Abstract*— Indonesian national curriculum (K-13) particularly geography's syllabi for X, XI, and XII grade students was created with strongly contain of spatial thinking. K-13 represents how geography education world should be, it was briefly underlined a point view of geography. Moreover, it is also consisting of spatial thinking dimensions as its main frame. The aim of this research is to investigate two spatial thinking aspects among second year student who are also a geography teacher-candidates based on several variables such as field-course experience, and several course achievements. Spatial thinking ability assessed by researcher used STAT Instrument. The result depicts unusual pattern that there is no significantly statistic different between STAT score towards course achievements. In conclusion, it is extremely important to emphasizing spatial thinking ability for geography teacher-candidates in order to prepare their pedagogical competency.**

Keywords— Spatial Thinking, Spatial Thinking Dimension, Spatially Course, STAT Instrument, GIS.

I. INTRODUCTION

Spatial thinking was commonly acknowledged as fundamentally point of view in geography, its physical and non-physical domains currently studied by spatial thinking with geographic-spatial approach as a vehicle. Spatial thinking is an excellent supplement for people who put their major as well as their interests in geography and geography education. On the other hand, spatial thinking is one form of thinking, it elaborates three main elements: a concept of space; tool of representations (maps, graphs, pictures, etc.); and cognitive process [1].

Spatial Thinking is a one way of thinking to solve numerous problem with understanding what space is and helped by modern technology to produce representation tools in instance Geographic Information System (GIS). Although, there are variously enough of information systems instead of GIS, it lead the way with its separation. All above effectively bundled with cognitive process inside human logic.

Everything in this world has its own space, exist, and relates to other object nearly or even far away in terms of distance. By combine spatial knowledge and spatial way of thinking, human have an adjustable and exaggerate way of thinking [1]. Additionally, GIS will always behind that way of thinking to managing, backing up, and supporting until human find the problem solving or solutions.

GIS is a set of computer system with a lot of benefit for spatial information management regarding the surface of earth [2]. The information or the data would be manage in form of data saving; data analyzing, and data recalling for mapping and planning needs. On one hand, GIS is a full package of software widely used for looking and analyzing geospatial data [3]. GIS has unique character compare to other information systems because the information of the phenomena has a detail in spatial attachment such as coordinates and address [3]. Geography may have a large range of field study well-known as a geosphere. The hugely scale of geography's objects seems to be effortless to learn because geography has a comprehensively work components and tools among spatial thinking, geographic-spatial approach, and GIS infinitely.

Furthermore, GIS is quite relevant since nowadays we are in the middle of the rapid growing of information and technology-industrial age. An intelligent in GIS technical operational could perfectly answer the global technology-industrial challenge. It has an abundant user-range namely banking, insurance, real estate, business property, government, transportation industrial, public safety, health and human services, not to mention education some of them were never expect to use GIS before [4]. At the present time education and GIS is no more debatable, it indeed not an act of impose to blending GIS and education. It is absolutely matched since education and GIS are strengthen each other in instructional process whether in a class room or in out-door courses. Despite currently GIS software capability away greater than education demands especially K-13 (Curriculum 13: Indonesian National Curriculum) to operate all of its functionalities. As a frame of scientific process, problem solving, visualization system, modelling, scaling and so forth, GIS was reveal its supreme potential to use as instructional media in education [1].

Instructional process in education is a perspective of a system, its components which are the instructor (teacher), learners, materials, instructional activities,

delivery system, and learning and performance shall interact during its process and continually affecting each other [5] [6]. At the same time, instructor has a responsibility to prepare instructional process including preparedness, materials, delivery system in a fancy activities, and evaluation systematically [5] [7]. Hence, it is undeniable that instructors have a vital role in transfer knowledge procedure for assured whether the learners understand the materials or not.

A seriously problem for a geography instructor-candidates' (university student majoring in geography education) occur when they lack of competency notably in spatial thinking ability. The K-13 curriculum comes and offering a different point of view of geography to teach geography materials for X, XI, and XII grade students (Fig. 1). The whole geography syllabi inside K-13 and its perspective in geography were full with geographic-spatial approach and spatial thinking where obviously need GIS as supporting system. Put more emphasize, K-12 United State primary education curriculum is powered by GIS as GIS was met 6 from the 10 benchmark for the scheme of a support system in K–12 education curriculum [1]. Besides, geography can highly attractive generally in any domain of education if all instructor did articulate and pull it to the surface rather than mathematical and verbal thinking [8].

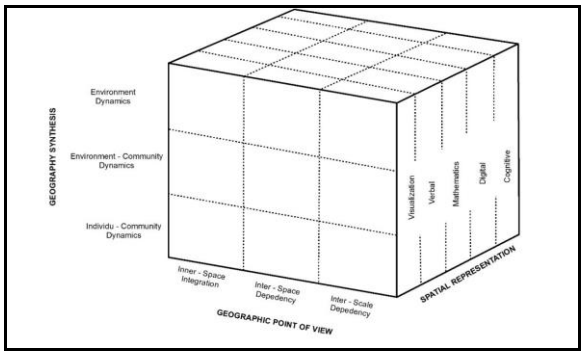

Fig. 1. Geography Perspective in K-13 Education

A deeper understanding of spatial thinking for geography instructor is inevitably since they were in a college or as early as possible as its urgency and advantages for instructor later in the following time. A set of field-course that prepared based on spatial thinking dimension is a very good example to start such argumentation. Further, it is a plan for geography instructor-candidates' to causing their pedagogic competency more accomplish and more well-prepared before they teach pupils in real education setting.

II. Spatial Thinking

There are some across discipline scholars tend to indicate the differentiation among spatial thinking variables most of them focused on gender, psychological matureness, K-12 education, and academic experience as NRC report mentioned [10] [11] [12] [13] [14]. Further emphasis, Alarasi in his research said implicitly the rural-urban environment, demographic background, and economic class also take a role in spatial ability as it is determined to the technology access [15]. In this case researcher is trying to discuss K-13 geographic point of view and bring together in the first place with condition in university where teachers were prepared to real setting of education especially in Indonesia. For the record it is a grass-root movement because it included just a University which called Muhammadiyah University of Surakarta (UMS).

Geography Education Standard Project has been mentioned the purpose of studying geography in 2004 and spatial thinking is one of the main keys and whether it can be achieved or not is depending on teacher practice, curricula, textbooks, and assessment [9]. On the back hand, many same studies highlight their research only in the spatial thinking variable scope.

Meanwhile, Jo and Bednarz focus on the textbooks they start with analyzing spatial properties from four textbooks from Texas Education Agency in 2003 for geography high school course, the four textbooks have an equal characteristic for instance organization and structure [9] [16]. Before the textbook analyzing process, they derived a synthesis about spatial thinking taxonomy from its definition as amalgam of three element concept space, using tools of representation, and cognitive process. From the spatial thinking definition, they write subcategories accompanied by a lot of review literature of the relevant study result (Fig. 2).

STAT is a standardized instrument to assess spatial thinking ability it was developed by Lee and Bednarz in 2011 and already tested both of its reliability and validity [14]. Even tough, the instrument made before the conception of spatial thinking dimension published the whole content is represent all of 24 subcategories dimensions.

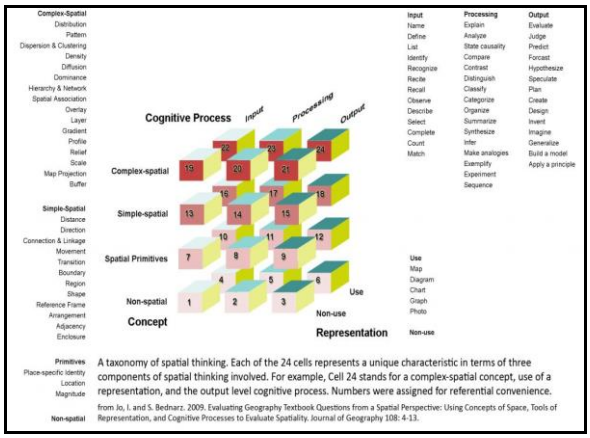

Fig. 2. Three-Dimensional Taxonomy of Spatial Thinking

A spatial thinking study conducting in Rwanda (east Africa country which basically third-world country) rural and urban area adjust the STAT instrument to Rwandan ordinary units, layout, native language therefore they can answering STAT question with no technical difficulties [13].

TABLE I. STAT QUESTION ITEM ORGANIZATION.

Type	Spatial Thinking Aspect (s)	STAT Question Item
I	Understanding Direction and Orientation	1, 2
II	Identifying Map and Graphic Information	3
III	Locating Best Location Based on Several Spatial Variables	4
IV	Imaging Slope from Topographic Map	5
V	Relating Spatially Distributed Phenomena	6, 7
VI	Visualizing 3D Image from 2D Information	8
VII	Overlaying and Dissolving Map	9, 10, 11, 12
VIII	Understanding Geographic Features: Point, Line, Polygon	13, 14, 15, 16

a. Collins, 2017

Rwanda study separate 222 students into 2 major groups, one group come from rural area and the others locate in urban area and used all of STAT items and aspects [13]. This research however, assess the spatial thinking ability after they finish field-course and divided them from their achievement in some theoretical and application courses. Rwandan research just start to introduce spatial thinking to Rwandan curricula while K-13 is already adapted spatial thinking as a framework.

III. DATA ACQUISITION

The research was conducted both in a campus and Prambanan Sub-district in very tight collaboration with Department of Geography Education, Faculty of Teacher Training and Education, Universitas Muhammadiyah Surakarta. The study involved second year teacher-student and field-course advisors. The research was held by first week of February and finished by the fall of May 2018. It included approximately 90 second-year geography teacher-students.

First, Data was gathered from very early field-course activities which consist of observing how good feature line and polygon for building-units mapping at Prambanan Sub-district, Central Java Province Indonesia in high resolution image-scale retrieved from google-map image. The quality of data vector checked by a group of senior-students and advisor who acting as Quality Control (QC) and Independent Quality Control (IQC) respectively. From this phase researcher believes instructor-candidates learning the concept of spatial representation: point, line, and polygon.

Secondly, instructor-candidates asked to survey building-unit in order to ensure building-unit geometric shape, building-unit existence and absolute location, building-unit utilization, land-use, and administrative boundary. Teacher-student also asked to provide an interview to local citizen or man-in-authority who lived just nearly administration boundary of Prambanan Sub-district and demanding to tell what and where the exact boundary of villages or Prambanan Sub-district, this method then called simple-interview GIS in this research. This step was taken because there was an ambiguity regarding the Prambanan Sub-district boundary and to identified the real condition of building-units. In this stage however, teacher-students are also experienced three primary categories of spatial taxonomy like concept of space, tools of representation, and cognitive process and without any doubt its sub-categories.

Thirdly, a week after field-course activities end researcher asked instructor-candidates to answering six items of STAT instrument question. This main data research will bring an information of how differentiate teacher-students spatial thinking ability after they finished map producing process and some course achievement. Lastly, data analyzing by describes the map as a spatial thinking dimension representative and provide a statistic of STAT score the detail will be show in forward section.

A. *Spatial Thinking Dimension*

The data of Spatial thinking dimension is qualitative data based on observation conducted by researcher since designing field-course process for teacher-student a couple of months before field-course activities. It actually analyzing by matched the design and the product which is building-unit and administrative features map of field-course location through spatial thinking dimension categories. There is three primary categories where each categories have sub-categories of spatial thinking dimension namely concept of space, tool of representation, and reasoning process [9].

The design and product then matched to spatial thinking dimensions sub-categories start from concept of space that involve non spatial, primitive spatial, and complex spatial. Further, sub-categories from use of representation tool divided to using and not using representation tools. It continue with input, processing, and output as sub-categories of third primary categories. Note that every sub-categories have additional aspects (Fig. 2.).

B. *Spatial Thinking Ability*

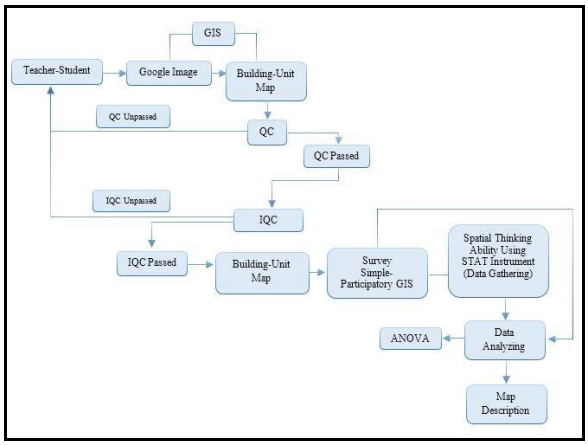

Fig. 3. Illustration of Research Workflow

First of all, researcher coding the data then grouped by courses achievement. The data then tested its normality, homogeneity and then analyze utilizing one-way analysis of variance (ANOVA) statistic as the

data will separate in several group to perceive variation among teacher-student.

Spatial thinking ability in this research become a dependent variable while the independent variables are group position, GIS-course achievement, and Cartography Thematic course achievement a semester ago. Each variables have diverse categories to compare for example group position has leader mapping, and ordinary member as a categories. Both of GIS and Cartography Thematic course achievement were separate into several group A, AB, B, BC, and Others (C, D, E) groups of grade of achievement. ANOVA statistic will reveal the variation spatial thinking ability amongst teacher-student from spatial thinking score means for GIS and Cartography Thematic Courses while non-parametric independent U-test from Mann-Whitney conducted for group position.

IV. Result and Discussion

A. *Field-Course and Spatial Thinking Dimensions*

Administrative map of Prambanan Sub-district (Fig. 4.) was fully prepared and created by teacher-candidate under researcher advisory. The map consist of many layers in assembling process utilizing software Arc. GIS 10.2. It is noticeable that the map main frame has two major polygon layers colored red with thick black outline and pale-green with variation of outline as boundary classification.

The red polygon layer indicate general Prambanan Sub-district boundary before it reshape based on local knowledge information and the data actually comes from Indonesian Department of Geospatial Information well-known as Badan Informasi Geospasial (BIG) year of 2004. The pale-green polygon layer is new version of Prambanan Sub-district boundary assembled by teacher-students using information they have been collected during field survey and interview.

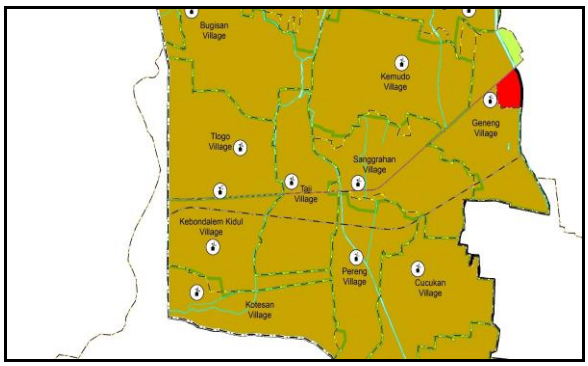

Fig. 4. Simple Interview GIS Result Map

Survey and simple interview to enhance the real boundary, administrative office coordinate supported by a mobile application installed in teacher-students' smartphone called Carry-map Observer. Carry-map (Cmf) file extension and used it as a guide to do navigation as well as exploration at the Prambanan Sub-district boundary and building-unit survey they had mapped. Carry-map widely use to carry GIS data and associated extension for ArcMap.

A spatially cognitive ability in order to operate GIS software such as ArcMap and Carry-map is extremely needed, and such form of thinking is constantly trained during the field-course since mapping preparation until survey. Researcher believe this mapping process using GIS software, Mobile offline map application, and simple interview method is a good example of training implementation of two element of spatial thinking ability aspects namely Type I: Understanding Direction and Orientation and Type II: Understanding Geographic Features: Point, Line, Polygon (TABLE I.). Therefore, this research conducted a test using STAT instrument to measure that two spatial thinking aspect teacher-student mastered ability.

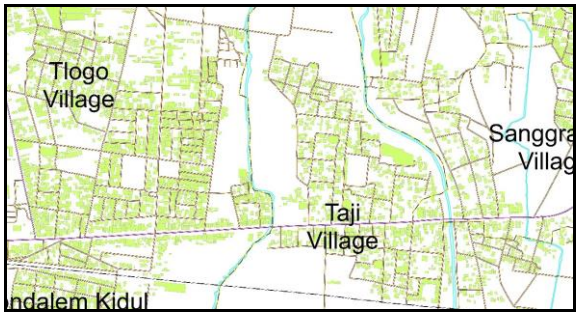

Fig. 5. Building-unit Map of Prambanan Sub-District.

Survey and simple interview to enhance the real boundary, administrative office coordinate supported by a mobile application installed in teacher-students' smartphone called Carry-map Observer. Carry-map act as a mobile-offline application help where a largescale map showed Fig. 6. Compressed into .Cmf file extension and used it as a guide to do navigation as well as exploration at the Prambanan Sub-district boundary and building-unit survey they had mapped. Carry-map widely use to carry GIS data and associated extension for ArcMap.

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B. *Spatial Thinking Evaluation*

The statistic test begin with non-parametric independent t-test to measure and proof whether there is a significant different between team-position. It used non-parametric because it was not normally distributed. The design of field-course made the 4th

semester teacher-student separate into 16 teams each team consists from 5 to 6 students and they mapped and surveyed 16 villages in Prambanan Sub-district, Klaten District, Central Java Province. Each team has a student that act as what we called Leader-Mapping while the rest Ordinary-Member. Leader-mapping determined by course advisors including me based on our observation in their above average performance in performing GIS software (ArcMAp), Course Assignment, and their leadership. This decision also based on fact that spatial thinking is affected by widely various factors [1] [10] [11] [12] [13] [14]. Leader-mapping will organize their teammate to create a big scale map of Prambanan Sub-district using recent google image.

TABLE II. FORMATION OF TEACHER-STUDENTS ACCORDING POSITION IN THEIR TEAM

Team Position	# of Students	% of Students
Leader-Mapping	16	19.75
Ordinary-Member	65	80.25
Total	81	100

TABLE II. depicts the number and the percentage of student grouped by their position in their team there are 16 teacher students as leader mapping and 65 are ordinary member or about 19.75% and 80.25% of teacher student consecutively. TABLE II. display the number of team position. The Mann-Whitney U-test (sig. value 0.287) found that there is no significantly different between leader-mapping against ordinary member group with 0.05 alpha level. The most distinguish feature of this table is there was at least one teacher-student that achieved perfect score while the highest score for leader mapping group was 5. Although, the mean of spatial thinking score of leader mapping is (3.13) and the other group is (2.86). This implies from a good leadership that belong to leader-mapping selected by field-course advisors based on long and ongoing observation students as spatial thinking ability also affected by psychological matureness [1].

TABLE III. ORGANIZATION ACCORDING POSITION IN TEAM

Team Position	Total Possible Score	Highest Score	Lowest Score	Mean
Leader-Mapping	6	5	1	3.13
Ordinary-Member	6	6	0	2.86

Table IV shows the formation of teacher-student who took role as a respondent and filling the stat instrument according cartography thematic course achievement. they were divided into five groups according their achievement for course relating to spatial thinking ability called cartography thematic. the groups named with grade of achievement such as a, ab, b, bc, and the other group consist of mixed grade of achievement such as c, d, and e.

TABLE IV. FORMATION OF STUDENTS ACCORDING CARTOGRAPHY THEMATIC COURSE ACHIEVEMENT

Grade of Achievement	# of Students	% of Students
A	7	8.64
AB	9	11.11
B	16	19.5
BC	24	29.63
Other	25	30.86
Total	81	100

In the following will appear typically same table based on GIS course achievement. Although, there were 97 teacher-student took Field-Courses it was only 81 teacher-students completed Field-Course, Cartography Thematic, and GIS courses. We selected them that already finished all of three courses mentioned above as research subject to evaluate their spatial thinking ability. The ANOVA (sig. value 0.609) used 0.05 alpha level revealed that there is no spatial thinking ability differentiation significantly exist among teacher-students according their achievement in Cartography Thematic Course. The most striking feature of TABLE V. was the average score of teacher-student included into A-Grade group was highest (3.29) while the AB-Grade group was the lowest (2.56) (TABLE V.).

TABLE V. AVERAGE ORGANIZATION ACCORDING CARTOGRAPHY THEMATIC COURSE ACHIEVEMENT

Grade of Achievement	Total Possible Score	Highest Score	Lowest Score	Mean
A	6	6	1	3.29
AB	6	4	1	2.56
B	6	6	0	3.25
BC	6	5	1	2.79
Other	6	6	1	2.84

TABLE VI. below illustrates the response of teacher-student to their spatial thinking ability according GIS course achievement. There are only four groups of achievement course because I combined the BC-Grade group into the Other-Grade group instead of deleting it. The number of Other-Grade group for GIS courses formed by one teacher-student who had BC grade and the rest had E grade of GIS course achievement. The teacher-student achieved A, AB, B grade are 5, 14, and 59 respectively. The reason of the elimination because it only just contains one student and it is causing trouble while performing ANOVA statistic operation, therefore the number of GIS course achievement groups different than Cartography Thematic course.

TABLE VI. FORMATION OF TEACHER-STUDENTS ACCORDING GIS COURSE ACHIEVEMENT

Grade of Achievement	# of Students	% of Students
A	5	6.17
AB	14	17.28
B	59	72.84
Other	3	3.70
Total	81	100

TABLE VII. Display the mean of spatial thinking ability teacher-student according their achievement for GIS course. The prominent feature of TABLE VII. is that the highest mean in two spatial aspect ability mastered by student-teacher who had AB-grade achievement by 3.21 while the mean of teacher student included in other-group was 2. The grade of GIS course achievement was descriptively implying to their sense of two aspects of spatial thinking particularly AB-grade group and Other (C, D, E) grade group course achievement.

TABLE VII. AVERAGE ORGANIZATION ACCORDING GIS COURSE ACHIEVEMENT

Grade of Achievement	Total Possible Score	Highest Score	Lowest Score	Mean
A	6	4	2	3
AB	6	6	1	3.21
B	6	6	0	2.86
Other	6	3	2	2.33

The ANOVA test observation value shows there is also no significantly different in teacher student spatial thinking ability according achievement in GIS course (sig. value 0.683). It continuously retain the H_O hypothesis and the overall result of two ANOVA statistic does not reflect the differentiation of spatial thinking ability between teacher-students as advanced research mentioned [8] [12] [14] [10] [18] [13]. However, that was just bolding the previous studies conducted by some scholars. It need to understand that this study only measure two out of eight spatial aspects this decision had taken because all teacher-student done in Cartography Thematic, GIS, and Field-course before also under frame that two aspect as mentioned above which are Understanding Direction and Orientation and Understanding Geographic Feature: Point, Line, Polygon.

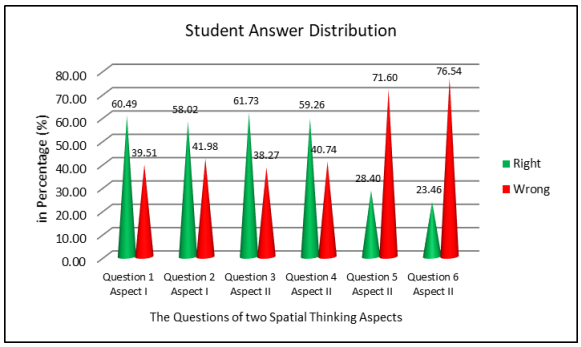

Fig. 6. Student Answer Distribution.

The un-significantly different among teacher student spatial ability according course achievement may the scientific proof of fruitfulness from the design of field-course that enhancing, improving, and comprehending all teacher-student understanding regarding two spatial thinking aspects therefore no significantly different since the students come from same academic background level or homogeneous population. The result also supported with some view part of Verma, Hardwick, and Lee and Bednardz studied, they generally mentioned geography where in this study represented by courses relies on the multidimensionality of spatial thinking, geography also bring together with a positive influent for spatial thinking ability, the more student taking geography course it triggered more excellent spatially literation for them [10].

Although, the statistic found there are no significantly different in general, but we need to know how the right and wrong answers distribute in order to reveal which aspect did students mostly mastered. Put more emphasize on that I drew a diagram on Fig. 7. above to provide clear view of answer distribution. The most prominent feature of this data is that over 70% students cannot correctly answer question number 5 and 6 which are retrieved from aspect 2. There are just below 42% student also cannot answer question number 1, 2, 3, 4. The highest amount of student in right way is question from aspect number two by approximately 61%. However, we should underline that it was only one question out of four. More importantly, there are over 57% students answered correctly question number one and two which are derived from aspect 1. In addition, this was indicated that the population of student mostly mastered spatial thinking in terms of aspect one rather that aspect 2.

V. CONCLUSION

The result brought a clear view regarding the very dependently spatial thinking ability towards other multi-factors where it cannot delineate the limitation with less consideration. The limitation we draw on that would be minimizing the result of the research. Geography Education UMS has a very good example in terms of prepared spatial thinking ability's teacher-students. Even though, the field-course framework and material mentioned in this research is useful to provide a model for prepare spatial thinking ability there is remain a dozen of detail to improve such as to accommodate all 24 level of spatial thinking dimensions as well as eight spatial thinking aspects intensively because almost all of teacher-student only could answer a half out of six question from STAT instrument provided. In addition, all of geography education department particularly in Indonesia should provide a special circumstance in pursuit K-13 geographic point of view that fundamentally build under spatial way of thinking. In the end, researcher believe it needs a wide coordination systematically both primary and secondary curriculum education to achieve spatial literation nationally.

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