OPPORTUNITIES TO DEVELOP STATISTICAL LITERACY: A COMPARISON OF STATE STANDARDS TO GAISE II

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In today's polarizing political climate, there is a need to build citizens' statistical literacy to combat misinformation and support data-based arguments. To that aim, we investigate K-12 standards documents for their alignment with the American Statistical Association's Guidelines for the Assessment and Instruction in Statistics Education (GAISE II). We found that the states that explicitly reference GAISE or had standards that explicitly addressed the statistical investigative process did not offer consistent opportunities for students to engage in each element of the investigative process and at each developmental level. We discuss the implications of the findings and provide recommendations for policy makers and standards writers.

Keywords: Data Analysis and Statistics, Policy, Standards

The current political climate of the United States is polarizing, often fueled by inflammatory rhetoric. Messaging that attempts to use data-based evidence for proposed policies or statistics to explain the spread of a deadly disease is met with disbelief and the cry of "fake news!" Some politicians have pushed the public to mistrust data and have been aided by people leaning on partisan trust instead of statistical literacy. This has created a heightened sense of urgency among data scientists, journalists, and educators to foster statistical literacy in the citizenry across all age groups. In schools, statistics is generally embedded as a content strand within the larger K-12 mathematics curriculum and may be offered as a separate course for students at the high school level (National Governors Association Center for Best Practices [NGA Center] & Council of Chief State School Officers [CCSSO], 2010). However, many states do not include statistics as a formal area of study within their mathematics courses until students reach the middle grade levels. This has been met with some pushback by researchers (Confrey, 2010) and there has been a concerted effort in providing educators and policymakers with resources to improve access to quality statistics-related content. For instance, the American Statistical Association (ASA) developed and released the *Guidelines for Assessment and Instruction in Statistics* (Franklin et al., 2007), which has had some impact on the grades 6-12 content in the Common Core State Standards for Mathematics. To give further guidance to educators and policymakers on statistics literacy, the ASA has recently published an updated report entitled the *Pre-K-12 Guidelines for Assessment and Instruction in Statistics Education II (GAISE II)* (Bargagliotti et al., 2020). In spite of such guidance, the opportunities to learn statistics through state mathematics standards vary from state to state and many are not aligned to the GAISE reports (Dingman et al., 2013; Newton et al., 2011; Weiland & Sundrani, under review).

Objective

With the current reality of statistical literacy in the U.S. and the resources now available to aid in creating opportunities to learn statistics, policymakers have the opportunity to update and improve state mathematics standards with statistics learning goals in mind. To support such efforts, in this study we investigated present efforts at purposefully incorporating the GAISE framework into state standards. Building on previous findings (Weiland & Sundrani, under review), we utilize state standards documents that explicitly reference the GAISE framework to answer the following research question: *To what extent are state K-12 statistics standards aligned to the GAISE II Framework for states that considered the GAISE report in their revision process?* To answer this question, we will investigate states' current efforts at building statistical literacy through incorporating suggestions from the GAISE framework into standards and to provide policymakers and standards writers with recommendations for future standards work based on our findings.

Background

When the Common Core State Standards for Mathematics (CCSSM) were developed in 2010, they were adopted by 48 states. This move signaled a shift towards a national set of standards designed to provide students with equal opportunities to succeed in mathematics. However, some politicians and citizens felt that this was the federal government's attempt at taking control of K-12 education from states (Orrill, 2016), in spite of it not having a role in the writing of the standards. Further, educators and families were unclear on how to enact the new standards, leading to frustration with the implementation and assessment of the standards. As a result of political pressures, a multitude of states have revisited their mathematics standards. Furthermore many states have revised their standards because of policies that require them to pass new standards after a set number of years (Achieve, 2017). The process to rewrite standards differs from state to state and involve a variety of constituents.

In a larger study, Weiland and Sundrani (under review) found that some states have referenced external sources in their standards revision process. Of the states that have mentioned the use of additional documents, five specifically cite the GAISE framework in their K-12 mathematics standards document – Louisiana, Massachusetts, Ohio, Virginia, and Wyoming. Louisiana, Massachusetts, and Wyoming all include the GAISE report in their updated standards document references, but their standards still do not differ from the CCSSM statistics standards in any substantial way. Ohio has made changes to their statistics standards to explicitly include the GAISE report. Virginia is the only state that did not adopt the CCSSM and has therefore incorporated the GAISE report differently from the CCSSM. Additionally, while Kentucky does not reference the GAISE report in their standards document, they do explicitly use the four-step statistical investigative process referenced in the GAISE report in their grade 1-6 standards. This inclusion of the investigative process may come from textbook *Elementary and Middle School Mathematics Teaching Developmentally*, which makes use the GAISE report (Van de Walle et al., 2019), and is used as an external reference document within the Kentucky state standards (Kentucky Department of Education, 2019). The only other state to explicitly name the statistical investigative process in their standards is Ohio, but only in grades 6 and 7.

GAISE II Framework

The GAISE reports were developed by the statistics education community to support the development of statistical literacy at the K-12 level (Bargagliotti et al., 2020; Franklin et al., 2007). The reports emphasize the need for students to understand statistical concepts and reasoning. The reports differ from other policy documents as they do not detail standards to cover at each grade level, rather they provide three levels of development (i.e., level A, B, and C) around the statistical investigative process. The investigative cycle includes four steps: formulate question, collect/consider data, analyze data, and interpret data. Though the three levels seemingly follow a grade band trajectory, the GAISE authors clarify that a student cannot

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progress to Level B unless they have mastered Level A skills regardless of their age or grade. The second iteration of the report, GAISE II keeps the core of the original report, adds on to the framework, updates the language, and provides more recent examples. We use the GAISE II report in our standards analysis because it has been developed by the statistics education community, provides more detailed guidance than other standards documents, and has been recommended by the National Council of Teachers of Mathematics (2020).

Methods

Data Sources and Collection

The data for this study includes official standards documents from states in the U.S. that reference the GAISE report. The states were identified one of two ways, searching for "GAISE" or "Guidelines for Assessment and Instruction in Statistics Education" within the state's standards documents , or from a larger analysis, where we noticed a close alignment with GAISE framework, though not explicitly stated. The only states that met the criteria of referencing the GAISE framework and differing from the CCSSM were Ohio and Virginia. Louisiana, Massachusetts, and Wyoming referenced the GAISE report, but did not meaningfully alter their standards from the CCSSM, so we considered them together as a case using the CCSSM standards. Kentucky was also identified for this study. Although Kentucky did not mention the GAISE report within their standards document, the standards incorporated the statistical investigative process in a way that was clearly aligned to the GAISE framework.

Identifying Learning Expectancies

Because states use different structures to organize their standards, we decided to analyze what we call learning expectancies (LEs). Learning expectancies represent the lowest unit of standard designation that provide a unique learning objective within the official standards documents analyzed. Virginia's standards only incorporate one level of standards, so these were taken as the LEs in that state. Kentucky and Ohio standards may include two or more sub-standards that elaborate on the top-level statement, so the sub-standards were taken as the LEs, in place of the top-level statement (see Figure 1).

~~*KY.7.SP.2:* Use data from a random sample to draw inferences about a population with an unknown characteristic of interest.~~

> *KY.7.SP.2.*a. Generate multiple samples of categorical data of the same size to gauge the variation in estimates or predictions.
> *KY.7.SP.2.*b. Generate multiple samples (or simulated samples) of numerical data to gauge the variation in estimates or predictions.
> *KY.7.SP.2.*c. Gauge how far off an estimate or prediction might be related to a population character of interest.

Figure 1: Example of Standards from the grade 7 Kentucky Mathematics Standards

At the elementary level, many states do not include a formal statistics strand, but do include a Measurement & Data strand that include statistics-related content. Therefore, we included any standards from the Measurement & Data strand that were statistical in nature. At the middle and high school grade bands, we included standards from the Statistics & Probability strand. However, we did exclude a number of probability LEs that focused on the mathematical aspects of theoretical probability (Bargagliotti et al., 2020).

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Analytical Framework

In order for the findings to be useful to policymakers, standards writers, statistics education researchers, and educators, we analyzed the data utilizing the GAISE framework as our lens. We used a binary coding to identify which process element(s) each learning expectancy addressed and also determined what developmental level was appropriate for each LE. It is possible that a single LE could encompass multiple process elements and developmental levels, depending on the language used. We discussed and agreed upon all coding to ensure inter rater reliability.

Results

The number of statistics LEs vary by state and differ substantially by grade level (see Table 1).

Table 1: Number of Statistics LEs by State and Grade Level

	0	1	2	3	4	5	6	7	8	A1	A2	HS	Total
CCSSM	2	1	2	2	1	1	8	7	4			31	59
Kentucky	2	4	4	7	3	1	13	10	3			30	77
Ohio	2	1	2	2	1	1	11	11	4			31	66
Virginia	2	2	3	2	3	7	5	5	6	2	3		40
Total	**8**	**8**	**11**	**13**	**8**	**10**	**37**	**33**	**17**	**2**	**3**	**92**	**242**

Kentucky and Ohio utilize a great deal of the CCSSM language in their LEs, but have added, edited, or deleted some of the verbiage. Additionally, while it seems that Kentucky includes the greatest number of statistics LEs, many of them are smaller, discrete concepts covered in a single LE in the CCSSM. For instance, the CCSSM includes the following standard, “Generate measurement data by measuring lengths using rulers marked with halves and fourths of an inch. Show the data by making a line plot, where the horizontal scale is marked off in appropriate units— whole numbers, halves, or quarters.” This LE is broken up into two in Kentucky – “Generate measurement data by measuring lengths using rulers marked with halves and fourths of an inch” and “Show the data by making a dot plot where the horizontal scale is marked off in appropriate units – whole numbers, halves, or quarters.” Virginia, being the only state to not adopt the CCSSM in this study, greatly differs in content and number of LEs in each grade level. It is also important to note that Virginia does not combine their high school level standards into one grade band. Instead, their standards are separated by mathematics course. For the purpose of this study, we only included LEs Algebra 1 and Algebra 2, which are required for graduation in the state (see Table 1).

Alignment to GAISE II

The data were coded with respect to the statistical investigative process elements and developmental level. *Formulate question* LEs (5%) lead students to create or verify questions that are statistical in nature. *Collect and consider data* LEs (31%) focus on data collection strategies, bias, and simulations. *Analyze* LEs (74%) ask students to make meaning of a data set’s variability and distribution and create visualizations. *Interpret* LEs (45%) concentrate on summarizing, drawing conclusions, and making predictions based on the context in statistical problems. Statistical process elements are not mutually exclusive; one LE may be coded as one element or as many as all four elements. Because of the large overlap in LE language, Kentucky,

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Ohio, and the CCSSM all include a similar proportion of collect and analyze LEs in their state standards documents (see Figure 2). Ohio and the CCSSM also include similar proportions for the formulate question and interpret LEs. Kentucky deviates slightly – 10% of this state's LEs incorporate the formulate question element compared with 3% and 5% in the CCSSM and Ohio respectively and include 13% less interpret LEs than the CCSSM and Ohio. Virginia's LEs differ significantly, as the state does not include any formulate question LEs and incorporates the analyze element in almost every statistics-related LE.

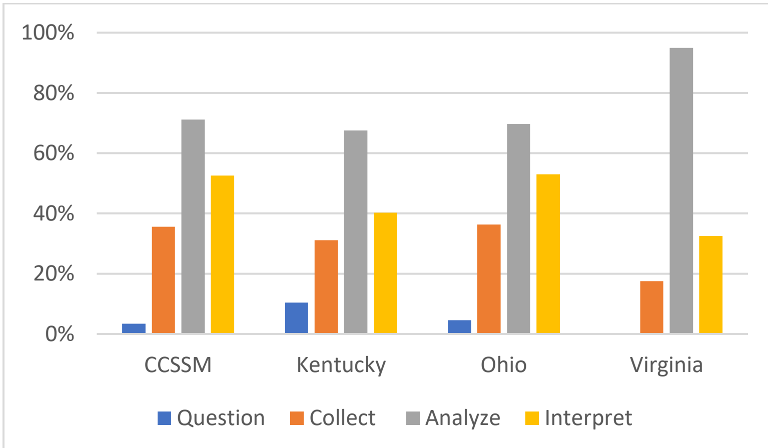

Figure 2: Bar Graph of Proportion of LEs for Each Statistical Investigative Process Element by State

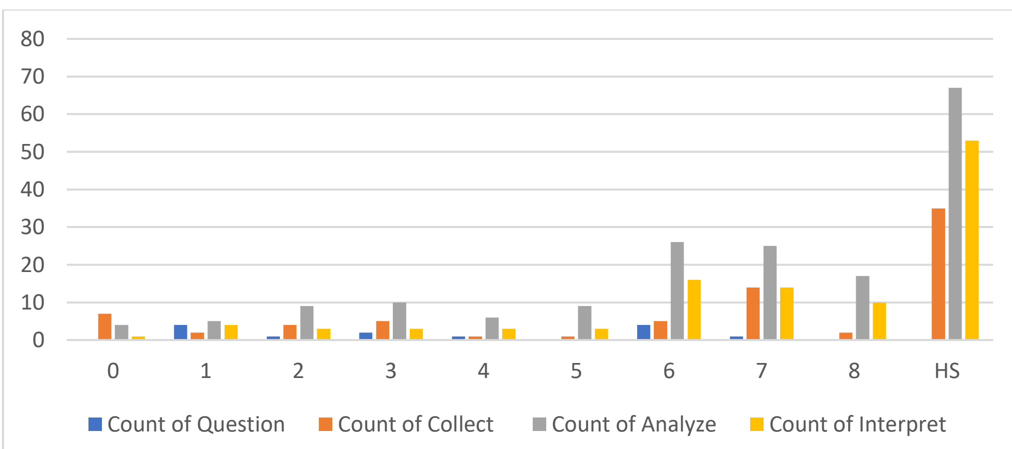

Figure 3: Bar Graph of Total Number of LEs by Statistical Investigative Process Element and Grade Level (N=242)

As the standards documents progress from grade band to grade band, the number of LEs generally increases as well (see Figure 3). In the CCSSM, Kentucky, and Ohio, as the standards progress from elementary to middle school grade levels, students have more access to the collect, analyze, and interpret elements. In the middle grade levels, formulate question LEs stay the same in the CCSSM, decrease in Kentucky, and increase by one in Ohio as compared to elementary grades. Virginia's statistics LEs provide students with more opportunities to analyze data in the

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middle grade levels, equal opportunities to interpret data in elementary and middle schools, no opportunities to formulate questions in either grade band, and less collect data LEs at the middle grade levels. The transition to high school adds more LEs on the collect, analyze, and interpret elements of the statistical investigative process in the CCSSM, Kentucky, and Ohio. It is important to note that while the number of statistics LEs increased in the high school grade band, this is potentially distributed over four grade levels. Again, Virginia differs and only provides a handful of experiences in the Algebra I and Algebra II courses offered to students. Overall, analyze data LEs make up the majority of students' experiences with data in the K-12 setting in all states, followed by interpret data, and then collect and consider data. Lastly, formulate question LEs are absent at the high school level in all four standards documents, continuing the pattern that as students move to higher grade levels, they have fewer opportunities to engage in the statistical questioning. Therefore, students have almost no experiences with formulating questions in the K-12 setting.

Approximately 26% of all LEs are at developmental level A, 34% are at level B, 41% of LEs are at level C, and 1% of LEs' developmental level is unclear typically due to vague wording. Kentucky, Ohio, and the CCSSM provide similar opportunities at each developmental level, whereas Virginia substantially differs (see Figure 2). Level A LEs are clustered in the elementary grade levels in all four state standards documents, while level B are mostly present in middle grade levels, and level C LEs are clustered in the high school grade levels. Grade six serves as a transition year as students move from level A LEs to level B. Virginia is the only state that does not provide any learning opportunities at level A for grade six students. During the middle grade years, most LEs are at level B, with a few experiences at level C. In high school, students gradually move from level B to level C LEs. Again, Virginia differs from the other three sets of standards, as it only includes level C LEs at the high school level. The CCSSM, Kentucky, and Ohio seem to align their LEs' developmental level with the recommendations from the GAISE II report. Formulate question LEs are only present at levels A and B in the CCSSM, Kentucky, and Ohio and as previously mentioned, formulate equations LEs do not appear in Virginia's standards. Collect LEs appear throughout the grade levels and cover all three developmental levels in all standards documents, except Virginia which does not include any collect LEs at level B. Analyze LEs are also split between levels A through C, with gradually more LEs at each level; again, the only exception is Virginia. This state provides equal opportunities for students to engage in statistical reasoning at levels A and B, but fewer opportunities at level C. Interpret LEs greatly increase as the developmental level increases with LEs almost doubling for as the level progresses in the CCSSM, Kentucky, and Ohio. This may mean that standards developers place increasingly more importance on the interpret element of the statistical investigative process but may not have provided enough opportunities at the earlier levels to support this move.

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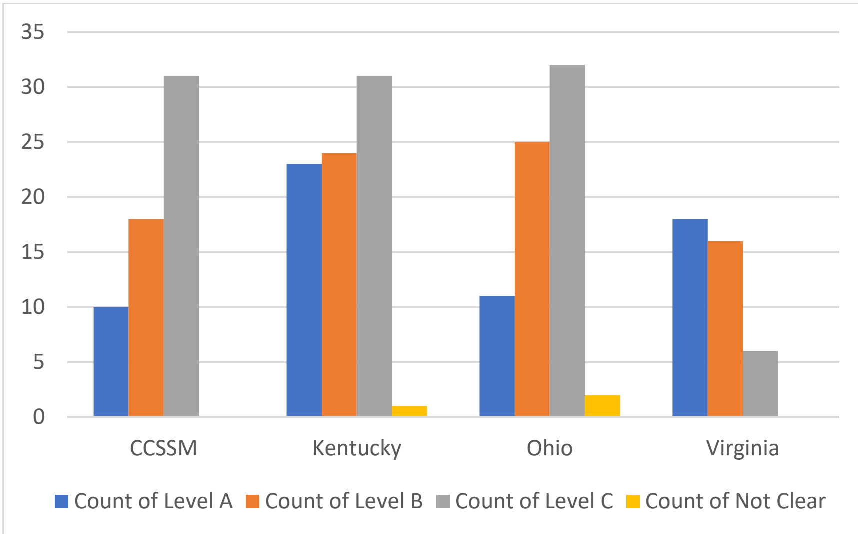

Figure 4: Bar Graph of Statistical Investigative Process Element of Total LEs by Developmental Level and State (N=242)

The GAISE II framework also details the need for students to experience different elements of the statistical investigative process in tandem. Therefore, it is also important to identify how many of the process elements are linked through the LEs in each state. The CCSSM and Ohio provide similar linkages, though Ohio's percentages of overlap between different process elements are slightly more spread out across the grade levels (e.g., the CCSSM provides no linkages in grade five, while about 2% of Ohio's overlap occurs in grade five). Both of these standards documents include some overlap between process components for over 80% of their LEs. The greatest proportion of connected elements is between analyze and interpret, followed by collect and analyze. Kentucky, as discussed above, has made a concerted effort to separate CCSSM language into smaller, discrete LEs. As a result, approximately 62% of Kentucky's LEs have some elemental overlap, compared with the CCSSM's 88% overlap. This has also created no opportunities for students in Kentucky to engage in multiple aspects of the statistical investigative process in grades K, one, and four. However, just like the CCSSM and Ohio, most overlap occurs between the analyze and interpret elements and then collect and analyze. Virginia offers the least proportion of linkages between process components, with only 55% of LEs combining two or more elements. Virginia also follows suit with the other three states in providing the most linkages between analyze and interpret and then collect and analyze.

Discussion and Implications

Overall, the CCSSM, Kentucky, Ohio, and Virginia offer some alignment to the GAISE II framework supporting student's development of statistical literacy to take on the demands of our data rich society. The most developed area is the support for students to move between developmental levels. Also, each standards document incorporates LEs that span the statistical investigative process, but do so in varying ways. Virginia, as the only state in this analysis that did not adopt the CCSSM, significantly veers from the statistical content covered and provides fewer opportunities for students to engage in each process element throughout K-12.

Through our analysis, we found few formulate question LEs. Virginia is the only state that did not include any LEs of this type, and Ohio and the CCSSM only included two and three LEs, respectively. These documents provide one LE at level A and the others at level B. Additionally, the first two opportunities to formulate questions is separated by four grade levels, making it difficult for students to build on prior knowledge. Kentucky was the only state to provide multiple opportunities for students to ask and identify statistical questions in grades one through six but did not incorporate any opportunities at the high school level. This element is crucial in teaching statistical literacy, as it is central to the statistical investigative process. Although all four states utilized the GAISE framework in designing their standards, there is still a need to purposefully include this element within the LEs and to connect it to other process elements across grade levels. Standards writers should consider including formulate questions LEs throughout K-12 and explicitly connect this element to the collect, analyze, and interpret elements to give students opportunities to engage in the entire statistical investigative process.

Another important consideration is the deliberate incorporation of all four elements in each grade level. Students need to have experiences with each process component throughout their K-12 careers to fully understand the purpose of each. Further, through repeated experiences with all four components at different grade levels, students will gain more consistent instruction at each developmental level. Kentucky creates the most consistent experience for students to engage in each component of the statistical process throughout K-12, with Virginia, Ohio, and the CCSSM following close behind. The CCSSM creates opportunities for students to engage in the entire statistical investigative process but does so sporadically. Ohio does not include opportunities for students to collect or consider data in grades one, four, and five. While the state does include more collect LEs overall, students do not receive instruction on collecting and considering data between grades four and five and are then expected to learn content at developmental level B in grade six. In addition, while each process component plays its role in developing statistical reasoning, students need to be exposed to the connections between each. Currently, there is significant overlap between process elements in the CCSSM and Ohio standards documents. Kentucky and Virginia do not include as many links, but do still connect at least two elements across their K-12 statistics LEs. However, most of the linkages offered in each state's LEs exist between the analyze and interpret elements. Without a solid grasp of how analyzing and interpreting data begins with statistical questioning and data collection, students will have difficulty developing statistical literacy. Therefore, we recommend that standards writers consistently incorporate LEs that provide students opportunities to experience each process element in isolation and together throughout K-12. Further, we recommend that researchers explore the impact standards on the instruction students receive at the classroom level.

One type of LE that was included in state standards documents that was missing from the GAISE II report is establishing the difference between correlation and causation. While this is an important statistical concept that every student should have the opportunity to learn, it is all but absent from the GAISE framework. Additionally, there is no formal mention of the normal distribution within the framework, despite the central importance of this concept within the statistics field. Therefore, it is important to note that the GAISE framework is an invaluable document, but should be supplemented by other statistics-related guidance.

While Kentucky, Ohio, and Virginia have used the GAISE report while rewriting their mathematics standards, each state has taken a different route to achieve this goal. Ohio's writing teams explicitly used the GAISE report when updating the mathematics standards and did not reference any other external resource in their standards document (Ohio Department of Education, 2017). Virginia's standards writing committee developed their mathematics standards using a number of impactful resources, such as the National Council of Teachers of

Mathematics's (NCTM) *Principles and Standards for School Mathematics* and the GAISE report (Virginia Board of Education, 2016). Kentucky did not include the GAISE report, but the standards writers in the lower level grades utilized the textbook *Elementary and Middle School Mathematics Teaching Developmentally*, which explicitly makes use the GAISE report in their tenth edition (Kentucky Department of Education, 2019; Van de Walle et al., 2019).

Each of the states analyzed referenced the GAISE framework when developing their standards. Despite this, each varied in their alignment to the statistical investigative process at each developmental level. This is due to a multitude of factors. Of note is the CCSSM, as Ohio and Kentucky have kept much of the language from this set of standards, influencing how much statistics could be incorporated into the standards documents. There also seems to be a disconnect between grade bands, particularly at the high school level. Additionally, statistics LEs are embedded within the larger mathematics LEs, restricting its space to one content thread among many others. Therefore, utilizing the GAISE framework does not seem to provide enough guidance to ensure appropriate alignment with the statistical investigative process. Policymakers and standards writers should aim to include teachers and university faculty with a background in statistics education in the standards writing process at all grade bands.

It is through the deliberate and consistent inclusion of the statistical investigative process throughout K-12 schooling and accompanying statistics concepts that students may develop their statistical literacy to become well-informed citizens, capable of interrogating data and the sources they come from.

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