

The Leonardo Laboratory: Developing Targeted Programs for Academic Underachievers with Visual-Spatial Gifts

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Abstract: This article presents a short-term program, The Leonardo Laboratory, for children with coexisting learning disabilities and spatial gifts. The program was developed in collaboration with a museum and administered as an after-school program to a group of elementary-school children (20 boys and 5 girls) so that its effectiveness could be evaluated preliminarily. Although the students in the program did not demonstrate statistically significant gains in academic skills, they demonstrated gains in self-efficacy and improvements in organizational skills. Thus, the program we developed has promise for certain kinds of skills and attitudinal development. Our work shows the importance of addressing the needs of children with disabilities and gifts (twice exceptional children).

Keywords:

Twice exceptional children, learning disabilities, spatial gifts, after-school program

Students with coexisting learning disabilities and special talents (twice exceptional children) are an often under-identified and under-served segment of the school-age population (Baum, 2004; Dix & Schafer, 2005; Kalbfleisch & Iguchi, 2008). Although some of these students are provided services for either their gifts or their learning difficulties, very few are identified for services that both develop their areas of weakness and allow them to explore their areas of strength (Bianco, 2005; Brody & Mills, 1997). This oversight may have significant consequences, both direct and indirect, on students' opportunities to succeed in careers that utilize their areas of strength (Johnsen & Kendrick, 2005). Directly, the students have little or no opportunity to develop their abilities and learn to compensate for their disabilities. Indirectly, this lack of services may create a lessened sense of self-efficacy. Ultimately, successfully intelligent individuals both capitalize on strengths and compensate for or correct weaknesses, so instruction should address both strengths and weaknesses (Sternberg & Grigorenko, 2007).

Given that these students require services both for their gifts and for their learning disabilities, there have been a number of documented interventions aimed at developing services specifically for this group of students. Predominantly, these programs are described in literature that covers case studies and anecdotal reports (e.g., Hua, 2002; Thrailkill, 2005; Turk & Campbell, 2005; Volker, Lopata, & Cook-Cottone, 2006); yet, there are a few illustrations of small-scale group-administered programs (see below).

In terms of their objectives, these programs can be classified into three groups. First, some are designed to address specific weaknesses these students possess. For example,

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one program utilizes a process-based remediation strategy to improve the reading skills of three students who have both gifts and learning disabilities (Crawford & Snart, 1994). Second, other programs address areas of weakness but are primarily designed to develop areas of strength through enrichment activities (e.g., Baum, 1988; Cooper, Baum, & Neu, 2004). One such intervention, Project High Hopes, sought to identify and develop scientific talents in students with special needs (Cooper et al. 2004). Finally, a number of programs are designed to develop areas of strength while remediating weaknesses (e.g., Bees, 1998; Weinfeld, Barnes-Robinson, Jeweler, & Shevitz, 2002). For example, the Wings program (Weinfeld et al., 2002) was developed to ensure that students with both gifts and learning disabilities have access to an enriched and accelerated curriculum, while also receiving instruction, adaptations, and accommodations in their areas of weakness through a cascade of services from integrated to self-contained classes, depending on each student's needs.

In addition to focusing on academic and cognitive skills, many programs acknowledge an additional goal of increasing student self-efficacy and self-regulation. Both the literature on students with gifts and the literature on students with learning disabilities describe children who are at risk for socio-emotional difficulties, such as poor self-concept and high levels of frustration and anxiety (Baldwin, 1999; Dole, 2000). Thus, a significant benefit can be provided by programs designed to increase students' self-efficacy.

While limited in number and scale, the literature on interventions for twice exceptional students provides some generalizations regarding advisable approaches to educating such students. One focal finding has been the importance of providing these students with a curriculum relevant to their gifts and talents (Baum, Cooper, & Neu, 2001; Neilsen & Mortoff-Albert, 1989; Weinfeld et al., 2002). The benefits of gifted-and-talented programming have been seen in both academic achievement and self-concept. For example, in a study of 76 grade 3 to 5 twice exceptional students, researchers (Neilsen & Mortoff-Albert, 1989) found that those receiving a combination of gifted-and-learning-disability services or only gifted services reported higher self-concept than those students receiving interventions exclusively focused on remediating weaknesses.

Another finding in the literature has highlighted the importance of having an individualized education plan that sets both strength-building and weakness-correcting goals (Baum et al., 2001; Cooper et al., 2004; Shevitz, Weinfeld, Jeweler, & Barnes-Robinson, 2003; Weinfeld et al., 2002). For example, the Wings program ensures that students have individualized and appropriate instruction and accommodations in their area of disability, while securing access to gifted programs or mentorships depending upon need (Weinfeld et al., 2002).

Pedagogical programs for students with both gifts and learning disabilities have not been rigorously evaluated. Yet, the preliminary evidence suggests that approaches addressing both strengths and weaknesses appear to have a positive impact on students' attitudes toward school and their commitment to academic work.

Prompted by the success of programs for students with learning disabilities whose gifts are in the analytical domain, and recognizing that strengths in other areas can promote success in life, we developed and implemented the Leonardo Laboratory program. This program was designed to address the creative and practical gifts of children who experience difficulties in academic subjects, but who have strong spatial abilities. Gifts that allow people to be successful in life can be found in a variety of domains, including strengths in visual-spatial skills or creativity and innovation (Aaron, Joshi, & Ocker, 2004; Mann, 2006; VonKarolyi & Winner, 2004). One goal of the Leonardo Laboratory program was to develop an enrichment curriculum that allows students to develop their identified strengths while at the same time identifying and remediating areas of weakness (Sternberg & Grigorenko, 2007). A second goal was to increase self-efficacy and enhance the self-regulation of these students, whose combination of gifts and disability has often not led to the development of adequate related skills.

The present project was designed to (1) identify students who have academic difficulties in reading, spelling, or math, while also displaying exceptional abilities in the creative arts (e.g., drawing, painting, or design) or in practical/spatial skills (e.g., model building); (2) develop an after-school program designed to address both the strengths and weaknesses of these students; and to (3) preliminarily evaluate the effectiveness of this program. Thus, we wanted to appraise findings from prior case-study and small-group research suggesting that when children with both gifts and learning disabilities are provided with a program that addresses their strengths, they demonstrate growth in areas of weakness that are targeted within the program (e.g., task approach and follow-through), even though they might not demonstrate improvement in areas of weakness that are not targeted (e.g., reading-related and math skills). We also wanted to validate a claim from prior research that students with both gifts and learning difficulties demonstrate growth in self-efficacy and self-regulation when provided with an intervention program that highlights their strengths and gives them opportunities to meet other students with similar learning profiles.

To summarize, this project was conceived to develop an intervention for children with coexisting spatial gifts and difficulties in reading/writing and/or math. In this article, we describe the intervention, comment on the feasibility of its implementation in after-school settings, and present some pilot data reflecting the promise of the intervention. Of note is that, although there are no formal estimates of the prevalence of double exceptionalities, the literature suggests that the number of twice exceptional children is low. Given this fact, recruiting a second group of twice exceptional children to serve as controls was not feasible, while a group of more typical students would not serve as adequate controls, being drawn from too different a population. Hence our study was done as a preliminary study only to assess whether there were any effects apparently associated with the program, with plans for a future controlled study if these minimal conditions showed any effects.

Method

Participants

The participating students were recruited through a brochure sent out to local elementary schools and families who had previously participated in programs at the Eli Whitney Museum (<http://www.eliwhitney.org/>) asking teachers and parents to nominate students in grades 4 through 6 who demonstrated, simultaneously, both learning difficulties and talents in drawing or building activities. A total of 33 students were nominated by their teachers and parents; of those, 30 students attended an evaluation session. Of these students, 11 were in grade 4, 14 in grade 5, 3 in grade 6, and 2 were being homeschooled. There were 24 male students and 6 female students, and the average age of the participants was 10 years 2 months ($SD=.81$). The program inclusion criteria were (1) reading, writing, or mathematics difficulties and (2) talent in at least one other area of endeavor (building, practical problem-solving, drawing). Of the 30 students assessed, one was reported as not having any learning difficulties at school, and one was not interested in the initial building project, and therefore deemed not well matched to the program. A total of 28 students began the program; 25 students completed the program. Table 1 presents the group by age, gender, and ethnicity.

Table 1. Means and Standard Deviations of Age, Grade, Gender, and Ethnicity of Program Participants

Age		Grade		Gender		Ethnicity		
<i>M</i>	<i>SD</i>	<i>M</i>	<i>SD</i>	Male	Female	Asian	African-Amer	Caucasian
10.12	0.67	4.60	0.71	20	5	4%	12%	84%

Project Site

The intervention program was designed in collaboration with and implemented by the Eli Whitney Museum (<http://www.eliwhitney.org/>). The Museum is founded on the ideas of industrial revolutionist Eli Whitney and seeks to encourage the resourcefulness, innovation, and entrepreneurship exhibited by its namesake through a unique tradition of learning via self-guided, hands-on problem-solving and experiences beyond the conventional classroom.

The Museum offers projects that begin in play and grow into art, architecture, engineering and science, and they include Japanese Toys and Technology, Rubber-Band Powered Cars, Aeromodeling, and Boat Building. The intervention program at the Eli Whitney Museum featured here was based on the works of Leonardo DaVinci and was led by the director of the museum, William Brown.

Procedure

To collect pilot data on the outcomes of the intervention, participants were assessed before beginning the Leonardo Laboratory program (Time 1, Pretest), then re-evaluated again at the completion of the program (Time 2, Posttest). The tests used were group-administered measures of nonverbal reasoning, math calculation, phonological and orthographical knowledge, and perception of task approach and follow-through skills. For performance assessment, students were asked to build a rubber-band powered car and their projects were assessed on two dimensions: (1) practical problem-solving and (2) creativity. In addition, parents completed a rating scale assessing their child's task approach and follow-through skills.

Targeted Skills

In designing the intervention program, the primary goal was to focus on students' strengths while developing areas of weakness. In a recent surge of research in developing self-regulated learning skills for children with learning disabilities (Harris, Reid, & Graham, 2004), self-regulation and the related concept of metacognition are described as encapsulating a number of skills, including (1) setting goals; (2) developing strategies to meet those goals (planning) (Butler, 1998); (3) consciously monitoring progress (Butler & Winne, 1995); (4) adjusting approaches as required (Butler & Winne, 1995); and (5) using motivation to cope with setbacks or obstacles (Corno, 1993). There is evidence that students with learning disabilities in postsecondary education continue to have difficulties with these task-approach and follow-through strategies, and that those college students with learning disabilities who employ self-regulation strategies are more successful (Butler, 1998; Trainin & Swanson, 2005).

The purpose of this intervention was to help students develop these self-regulation strategies – specifically task approach and follow through – while they completed projects that capitalized on their strengths and helped them practice compensating for weaknesses, including elements of reading/writing and doing math. The program also intended to increase children's self-efficacy.

Materials

Pretest measures included (1) a measure of nonverbal cognitive skills, (2) baseline measures of academic skills that were areas of difficulty for students as specified in the recruitment inclusion/exclusion criteria, and (3) a performance-based measure of practical problem-solving and creativity. For the academic skills, specifically, we assessed: (1) reading and reading-related skills (phonological processing, orthographical processing, and print exposure); (2) math calculation skills; and (3) achievement as indicated by a parental rating. We also collected measures on target areas that are often challenging for students with learning difficulties, including parent and child ratings of task approach and follow-through skills. We also administered a hands-on performance

measure to assess students' potential areas of strengths, including visual/spatial building skills, practical problem solving, and creative skills.

At posttest, we collected academic skill measures, including the reading and reading-related skills, math calculation, and student and parent ratings of task-approach and follow-through skills. A qualitative feedback measure was also obtained.

Nonverbal ability. The Cattell Test of "g": Culture Fair Scale 2, Form B (Cattell & Cattell, 2002) is a measure of nonverbal reasoning in which the student analyzes visual patterns, for example, determining missing parts or finding similar patterns. This test was administered at Time 1 to provide a benchmark level of cognitive functioning and to ensure that all students were of average to above average ability in nonverbal reasoning. Scores on this measure indicated that all students had average to superior ability: the average score for the group was 114.84 ($SD=14.30$).

Academic skills measures. The Title Recognition Task (Cunningham & Stanovich, 1990) gauges students' exposure to print. This test, consisting of a list of real and false book titles, was originally designed to predict reading experience in third- and fourth-grade children, but has been correlated with other reading-related skills in students in grades 5 through 9 (McBride-Chang, Manis, Seidenberg, Custodio, & Doi, 1993). Participants were instructed to put a mark next to the titles that they knew were real books. In addition, they were told that the list contained both real and false titles and authors, and therefore they were not to guess. This test has two versions and administration was randomly assigned at pretest, with the other version administered at posttest. Both versions have 25 real books; version 1 has 15 false titles, version 2 has 16 false titles. Scoring of this measure consisted of the percentage of real book titles selected minus the percentage of false titles selected. The same measure was administered at both pretest and posttest. *The Phonological Choice Task* (Gayan & Olson, 2001) is a measure of phonological-processing skill consisting of forced-choice decisions between pairs of nonwords that sound like common words if read aloud and two nonwords that do not sound like known words. Students were asked to circle the word in each row that sounded like a real word if read aloud. There are five practice items and 60 test items that were randomly divided into 2 sets of 30 items to create A and B versions of the test. Students randomly received either the A or B version at pretest and were given the alternate version at posttest. Scoring of this measure consisted of the percentage of correct responses. The same measure was administered at both pretest and posttest. *The Orthographic Choice Task* (Olson, Forsberg, Wise, & Rack, 1994) is a measure of orthographic-processing skill consisting of a forced-choice decision between a word and a phonetically identical pseudohomophonic nonword (e.g., take – talk). The task requires the participant to recognize the correct orthographic pattern for the word independent of its phonology. There are five practice items and 78 test items that were randomly divided into 2 sets of 39 items to create an A and B version of the test. Students randomly received either the A or B version at pretest and were given the alternate version at posttest. Scoring of this measure consists of the percentage of correct responses. The same measure was administered at both pretest and posttest. *The Woodcock-Johnson (WJ-III) Math Calculation Subtest* (Woodcock, McGrew, & Mather, 2001) provides a measure of a student's mathematical-computation ability. Questions progress through single-, double-, and triple-digit addition, subtraction, multiplication, and division. Harder items require students to perform calculations with fractions, decimals, and negative numbers. Students in the study were asked to complete as many questions as they could. Standard scores were obtained. The same measure was administered at both pretest and posttest.

Self-regulated learning measures. The Organizational Rating Scale (Parent-Report) is a measure developed for this project that asks parents to rate their child's behavior on a 5-point scale. The measure consists of 33 items assessing task-approach and follow-through skills such as planning, preparing, overcoming obstacles, and independence in completing home chores, school tasks, and extra-curricular tasks. This measure was administered at both pretest and posttest. *The Organizational Rating Scale (Child-Report)* is

a measure developed for this project that asks students to rate their own behavior on a 5-point scale. The scale consists of 36 items measuring self-perception of task approach and follow-through skills such as planning, preparing, and completing tasks at home and school. This measure was administered at both pretest and posttest.

Performance measures. *The Rubber-band-powered car task*, developed by the Eli Whitney Museum, gives students the parts and instructions for building a basic car powered by rubber-bands. The task was assessed on two factors (1) function (practical) and (2) form (creative). For the functional assessment, the student had to compete to see how far their car could travel compared with the cars of other students. The students were given trial and revision opportunities for testing their car. These trial and revision opportunities were limited in time but not in number, so students could try their car and revise as many times as they chose during a time period that was set for everyone. For the form assessment, students were provided with resources to make their car unique.

Qualitative measures. Qualitative feedback was solicited from both parents and students following the completion of the program. Parents were given a feedback form asking three questions: (1) please describe any benefits of the program for your child; (2) please describe any negative outcomes of the program for your child; and (3) please provide any additional information that you feel may be important for us in evaluating this program. Students were also given a feedback form with three questions: (1) please describe three things that made this program good for you; (2) please describe anything about the program that was not so good for you; and (3) please describe anything else about the program that you think was great or not so great.

Intervention

General overview. The program included a series of ten workshops that invited students to complete experimental building projects derived from Leonardo DaVinci's notebooks. Using activities initially sketched by DaVinci and further developed for the purposes of this intervention, the program integrated exercises developing important learning skills such as: (1) following the demands of the instructor while making projects on their own; (2) coping with environmental constraints, such as availability of materials and tools; (3) progressing through steps of the projects, i.e., planning, preparation, time scheduling, exploring, and follow-through; and (4) specific skills in following directions, overcoming obstacles, and recognizing their own successes.

Specific application of the goals. Each assignment allowed students to take responsibility and realize the choices available in directing or 'steering the project'. It also acknowledged the restrictions that can be placed on an assignment by facilitators (i.e., museum staff members), reminding the student that in most learning situations, there are boundaries that must be considered. Each project was also subject to environmental constraints, such as resources and time constraints that can push an endeavor forward, backward or in a different direction. At the start of each project, students were provided with the basic materials and instructions for completing the project. A demonstration of the steps for completing the basic model and examples of different ways of individualizing the project were provided. Additional resources were provided (e.g., bins of markers, scraps of wood, pieces of cloth, pipe cleaners, pieces of wire), and students were reminded that they could use any other resources found at the museum. During project building, facilitators circulated among the students, asking them about their plans, how they were going to reach their goal, and what they were going to need. The facilitators also reminded the students to consider the time available. No specific ideas were provided to the students, although they were free to talk amongst themselves and were encouraged to make the project their own. Each obstacle was presented as an opportunity for choice, a time for decision-making, or a lesson to be learned. In deciding how to overcome obstacles, students were supported by choices such as back-tracking and finding alternate ideas, methods, and materials. At the end of each session, students were taken aside individually and encouraged to consider the obstacles they had

encountered and overcome, the opportunities that had arisen, the opportunities captured, the set-backs faced, the discoveries or successes, the disappointments, and the lessons learned in their projects.

Results

Descriptive Statistics

To determine any significant effects of age and gender on the results, correlations were calculated between these three variables and the rating scales and the academic-skills measures. No significant correlations were found for age or grade with the Child-Report measure, the Parent-Report measure, or any of the academic-skills measures (phonological, orthographical, title recognition, or calculation) at either pretest or posttest.

Intervention Outcomes

The Parent-Report Organizational Rating Scale and *The Child-Report Organizational Rating Scale* were two new measures developed for this study. As these rating scales were new, we wanted to ensure their reliability across time. The child and parent scales showed a high degree of consistency with each other, indicating that children and parents tended to agree on the abilities of the children. With respect to the internal consistency of the items, the Child Rating Scale had a Cronbach’s alpha of 0.88 and the Parent Rating Scale had a Cronbach’s alpha of 0.91, demonstrating a high degree of internal consistency.

Given the pre/post design of this pilot study and the small sample size, paired-sample *t*-tests were conducted to determine any significant differences between the pre- to post-test academic skills and the pre/post child and parent-ratings on task approach and follow-through skills.

Academic skills assessed by group-administered tests of reading-related skills and math calculation skills showed no significant differences from pre to post test, neither on the omnibus, nor on individual tests. As these were not areas of intervention, this finding was expected (see Table 2 for descriptive and inferential statistics).

Table 2. Means, Standard Deviations, and T-test Data of Pretest and Posttest Measures of Reading- and Math-Related Skills

	N	Pretest		Posttest		Difference	
		M	SD	M	SD	t-score	p-value
Title recognition task	21	0.21	0.22	0.27	0.18	-1.00	0.33
Phonological choice task	18	0.64	0.25	0.65	0.27	-0.19	0.85
Orthographic choice task	22	0.84	0.12	0.85	0.13	-0.17	0.86
Math calculation task	22	93.06	14.69	95.39	15.64	-0.85	0.40

The parent-rating scale and child-rating scale assessed skills that were targeted in the intervention, and therefore, differences between pre and post ratings of parents’ and children’s perceptions of task approach and follow-through skills were expected. The parent rating scale showed a significant difference between pre and post ratings, with

scores rising following the intervention, indicating that, overall, parents saw an improvement in their children's task-approach and follow-through skills. In particular, the following items showed a significant positive change or approached a significant change in rating from pretest to posttest: (1) overcoming obstacles in completing a homework task; (2) leaving the house on time for school with minimal prompting; (3) following multiple steps to complete a household chore; (4) overcoming obstacles in completing a household chore; and (5) following instructions to complete a one-step household chore. The child-rating scale demonstrated no comparable rise (see Table 3), however, given that parents are the ones who provide all the support and/or reminders, they are likely the ones who notice change first. Of note also are the dynamics of the correlations between parent and child ratings at pre- and posttests (see Table 4).

Table 3. Means, Standard Deviations, and T-test Data of Pretest and Posttest Parent and Child Rating Scales of Task Approach and Follow-Through Skills

	<i>N</i>	Pretest		Posttest		Difference	
		<i>M</i>	<i>SD</i>	<i>M</i>	<i>SD</i>	<i>t</i> -score	<i>p</i> -value
Parent Rating Scale	17	56.42	12.78	59.84	2.37	-2.41	0.03
Child Rating Scale	13	122.62	19.09	126.15	16.20	-0.62	.55

Table 4. Correlations of the Pre and Post Administrations of the Parent and Child Rating Skills

	Pre Parent	Post Parent	Pre Child
Pre Parent	-		
Post Parent	0.89***	-	
Pre Child	0.72**	0.65*	-
Post Child	0.30	0.32	0.67*

*** $p < .0001$, ** $p < .01$, * $p < .05$

Qualitative feedback from parents converged on three themes: (1) the development of areas of weakness, for example, "he is more willing to sit down and do homework, less resistant, more persevering"; (2) the development of areas of strength, for example, "he continued to work on each project when he got home"; and (3) the development of self-efficacy, for example, "he doesn't shrug off his accomplishments." In general, parent qualitative feedback confirmed the findings of the parent rating scale that children showed improvement in areas of weakness. In addition, parents also indicated that children experienced benefits to their self-efficacy and developed further their areas of strength. Qualitative feedback from the students reflected primarily themes of self-efficacy, for example, "showed me I could do good things that people love and want."

Discussion

The results of the current study are consistent with the literature that suggests that students who have both gifts and learning disabilities benefit from programs targeted to developing their areas of strength. Although very preliminary and based only on informants' reports, this study provides some quantification of positive effects on the improvement of targeted skills by the intervention. The students who participated in this study diverged from those in previous studies in the fact that the focus was not on students who demonstrated cognitive gifts, but on those whose gifts were in the creative and visual-spatial domains. The intervention offered also differed in that students were delivered a program out of the typical school curriculum, focused on developing not only their strengths but also on areas of weakness that impact school performance. In particular, the intervention targeted skills in task initiation and follow-through, areas often found to be weak in students with learning difficulties. To quantify these skills, new measures were devised to obtain ratings from parents and students on the application of these skills from the intervention setting to outside settings, specifically, the home environment and especially homework tasks.

The new measures offered a way to capture parents' perceptions of students' strengths and weaknesses in task approach and follow-through. Parents reported significant improvement on a number of items. Finally, parent and student qualitative statements corroborated these findings.

One of the most important findings reported by both parents and students was the growth in self-efficacy and self-recognition of an area of strength. At pretest, many of these students were reported as experiencing social and emotional difficulties, including anxiety and sadness. Parents reported concerns that their children were exhibiting indications of learned helplessness in their school environments and were demonstrating less effort in their schoolwork. At the time of the posttest, both parents and students reported a re-engagement in goal-directed tasks and a sense that the student could accomplish something worthwhile. One indicator of this program's positive benefit to these students is the number of students who have continued to engage in programs at the Eli Whitney museum as both students and, later, facilitators, after first being introduced to the Leonardo Laboratory.

Yet, although this work resulted in the development of a new and engaging program, the data we present here are only preliminary and, though encouraging, should be interpreted with caution. To validate and strengthen our claims about the potential of the Leonardo Laboratory, a number of steps need to be taken. First, a formal effectiveness study with a large sample of participants and a control group needs to be carried out. Second, a battery of performance-based assessments capturing the skills targeted by the program needs to be administered using the pre-/posttest design. Here we used convergent information, provided by parents and the students themselves, but, as indicated above, this is only the first step in carrying out an evaluation of the program. Clearly, other adults, such as students' teachers and museum personnel can be included as additional informants. The positive feedback from parents and students might be indicative of wishful thinking for change, rather than change itself. Finally, the relationships that a number of the students subsequently built with the museum after their participation in the Leonardo Laboratory, although encouraging, should also be interpreted with caution: their comfort and satisfaction with the atmosphere of the museum might not be indicative of learning and change.

In summary, this report is only an initial presentation of a promising intervention program for children who have coexisting gifts and disabilities. With the program developed, the next step is to formally evaluate it. Hopefully, there will be future opportunities for that step to be made.

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