An Interactive Car Drawing System with Tick'n'Draw for Training Perceptual and Perspective Drawing Skills

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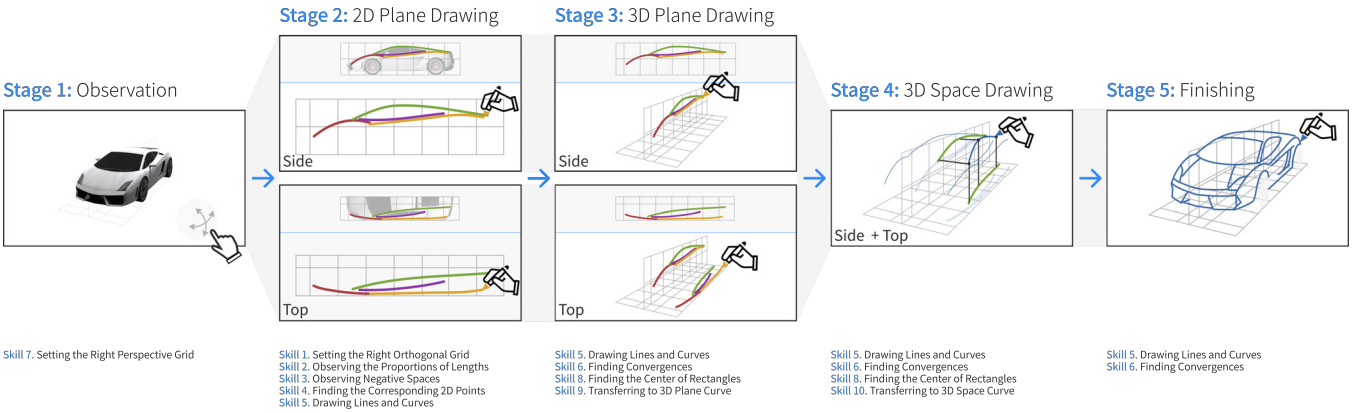

Figure 1: Our novel interactive system consists of 5 stages for drawing a nice car with an accurate perspective. The user follows the friendly guidance of *Tick'n'Draw* in ticking important points and drawing curves that pass through those points following the hint generated by the system and, in the process, repeatedly trains 10 core drawing skills to make them his or her own.

ABSTRACT

Young children love to draw. However, at around age 10, they begin to feel that their drawings are unrealistic and give up drawing altogether. This study aims to help those who did not receive the proper training in drawing at the time and as a result remain at that level of drawing. First, through 12 drawing workshop sessions, we condensed 2 prominent art education books into 10 core drawing skills. Second, we designed and implemented a novel interactive system that helps the user repeatedly train these skills in the 5 stages of drawing a nice car in an accurate perspective. Our novel interactive technique, *Tick'n'Draw*, inspired by the drawing habits of experts, provides friendly guidance so that the user does not get lost in the many steps of perceptual and perspective drawing. Third, through a pilot test, we found that our system is quick to learn, easy to use, and can potentially improve real-world drawing abilities with continued use.

CCS CONCEPTS

• **Human-centered computing** → **Interaction techniques**.

KEYWORDS

Perceptual drawing, perspective drawing, interactive education

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1 INTRODUCTION

Children's desire to draw realistically tends to grow faster than their drawing skills, and at around age 10, their desire outpaces their skills. At this point, for the first time in their lives, children experience frustration with their distorted drawings, which do not fit into perspective. A small number of children who discover how to draw in perspective on their own overcome this barrier and continue improving their drawing skills. However, many other children who do not receive quality instruction in drawing give up drawing altogether and live their lives with the drawing skills acquired at the time [1].

This study proposes a drawing education system that allows anyone trapped at this level of drawing to acquire the core skills of realistic drawing. Our system aims to develop the drawing skills in the natural process of completing an accurate perspective drawing from scratch, motivating the user to draw more subsequently. We chose cars not only because they are the objects that children

around the age of 10 want to draw most realistically [1], but also because, among the many objects we encounter in our daily lives, they consist of many aesthetic 3D space curves that are also a suitable material for training in drawing.

To draw a car realistically, it is necessary to follow the perceptual and perspective drawing method in which a series of steps are performed accurately in a predetermined order [1, 6]. However, it is easy for beginners to get lost in the many steps, and as failures accumulate, the drawing may become too messy to continue. To solve this problem, we propose the *Tick'n'Draw* interaction technique inspired by the drawing habits of experts. By drawing a nice car according to the friendly guidance offered by Tick'n'Draw, the user can understand the purpose of and repeatedly train the core drawing skills needed for each stage of drawing (Figure 1).

2 RELATED WORK

In art education, perceptual drawing refers to accurately observing and drawing objects as they appear. In *Drawing on the Right Side of the Brain* [1], Betty Edwards, famous for her classes tapping into the latent perceptual abilities of a layman to help him or her draw well within 7 days, suggests special ways to train perceptual drawing skills. On the other hand, perspective drawing refers to plausibly expressing and communicating forms as one imagines them. *How to Draw* [6] by Scott Robertson, famous for drawing concept art with perfect perspective using only paper and pencil, is widely used as a textbook in design classes thanks to systematic step-by-step instructions on perspective drawing.

There have been studies to incorporate these methods of traditional art education into an interactive system, and they have been found to enhance users' skills, confidence, and creativity. *PerSketchtivity* [10] provides exercises for drawing straight lines, circles, and cubes with immediate feedback. Keshavabhotla et al. [5] focus on 3D primitives such as cubes, cylinders, cones, and spheres. Williford et al. [9] provide feedback on lines that do not fit into perspective by analyzing the user's drawing. *Sketchtivity* [8] adds learning scenarios such as challenges, assessments, and games. In particular, *How2Sketch* [4] deconstructs the 3D model of an object into 3D primitives and automatically generates a step-by-step tutorial to draw each. While these systems focus on perspective drawing of 3D primitives, which serve as rough scaffolds for drawing the rest, our system focuses on perspective drawing of the actual 3D space curves, in addition to perceptual drawing.

There have also been studies to more aggressively enhance the user's drawings through active intervention by the system. In traditional perspective drawing, construction lines are drawn to serve as a rough reference before drawing curves detailing the form [3]. Spatial information can be extracted from these construction lines and leveraged to correct user-drawn 2D curves or to generate 3D curves from them [2, 7]. However, in this study, by helping users acquire a set of core drawing skills through repeated training with the guidance of Tick'n'Draw, including those related to construction lines, we hope to help them draw anything realistically in accurate perspective, without having to rely on the system to make changes on their behalf.

3 DRAWING WORKSHOP

We convened 12 drawing workshop sessions to derive the minimal set of core drawing skills and stages that the user must go through to draw the form they want realistically.

The drawing workshop was conducted with 12 industrial design majors, including the 3 authors of this study, for about 1.5 hours each for 10 sessions. In each session, the contents of 2-3 chapters of *Drawing on the Right Side of the Brain* [1] and *How to Draw* [6] were summarized, and the drawing exercises presented in the books were performed together. In total, 83 drawing skills appearing in 22 chapters of 2 books were analyzed (Table 1).

In addition, during the following 2 sessions, we simulated the processes of drawing a car realistically and identified 5 stages that are needed to determine the form of the car in 2D and to visualize it realistically in 3D. We focused on the 10 core drawing skills from the above 83 skills that are needed to observe the 2D form, to draw it using 2D curves, and to reconstruct a 3D curve from those curves in perspective (Figure 1).

Table 1: Of the 83 drawing skills presented in 22 chapters of 2 art education books, *Drawing on the Right Side of the Brain* [1] and *How to Draw* [6], 16 were selected and consolidated into 10 core drawing skills.

Drawing on the Right Side of the Brain
Ch 1. Drawing and the Art of Bicycle Riding
Ch 2. The Drawing Exercises: One Step at a Time
S1. Drawing Materials
Ch 3. Your Brain: The Right and Left of It
Ch 4. Crossing Over: Experiencing the Shift from Left to Right
S2. Upside-down drawing
Ch 5. Drawing on Memories: Your History as an Artist
Ch 6. Getting Around Your Symbol System: Meeting Edges and Contours
S3. Pure contour drawing (wrinkles in palm)
S4. Modified contour drwaing
S5. Utilizing the format as a constant
Ch 7. Perceiving the Shape of a Space: The Positive Aspects of Negative Space
S6. Negative space drawing
S7. Choosing a basing unit
S8. Sighting
Ch 8. Relationships in a New Mode: Putting Sighting in Perspective
S9. Sighting in perspective
Ch 9. Facing Forward: Portrait Drawing with Ease
Ch 10. The Value of Logical Lights and Shadows
S10. Crosshatching
S11. Drawing values as it is
Ch 11. Drawing on the Beauty of Color
S12. Expanding harmonious color
Ch 12. The Zen of Drawing: Drawing out the Artist Withing
How to Draw
Ch 1. Drawing Materials and Skills
S13. Ghosting lines
S14. Drawing parallel lines
S15. Aiming lines point to point
S16. Drawing a box in 1-point perspective
S17. Drawing a box in 2-point perspective
S18. Drawing curves through multiple points
S19. Drawing an ellipse
Ch 2. Perspective Terminology
S20. Finding vanishing points on the picture plane
Ch 3. Perspective Drawing
S21. Dividing a rectangle in half in perspective
S22. Duplicating a rectangle in perspective
S23. Multiplying and dividing boxes
S24. Dividing into odd-numbered proportions
S25. Mirroring horizontal planes
S26. Mirroring vertical planes
S27. Mirroring offset planes
S28. Mirroring tilted planes
S29. Mirroring rotated and tilted planes
S30. Mirroring 2D curves
S31. Mirroring a 2D curve on a tilted surface
S32. Mirroring 3D curves in perspective: 2-curve combo
Ch 4. Creating Grids
S33. 1-point grid construction
S34. 2-point grid construction
S35. Rotated 2-point grids with same-sized squares
S36. Transferring scale in perspective
S37. The Brewer method
S38. Creating a grid of squares
S39. Underlay
S40. Assembly and exploded views
Ch 5. Ellipses and Rotations
S41. Ellipse basics and terminology
S42. The minor axis is key
S43. Placing a circle in perspective or drawing ellipses
S44. Creating a cube using ellipses
S45. Offsetting ellipses
S46. Hinging and rotating flaps and doors
S47. Subdividing ellipses
S49. Shortcuts to dividing ellipses
S48. Spirals
S50. Placing a circle on a sloped surface
Ch 6. Working with Volume
S51. Planning before perspective
S52. Orthographic views
S53. Transferring a side view into perspective
S54. Putting it all together: X-Y-Z Section Drawing
S55. Extending the sections
S56. 2-curve combo
S57. Cutting volumes
S58. Adding radii and fillets
S59. Wrapping graphics
S60. Detaling and sculpting surfaces
S61. More tips for modifying complex volumes
S62. Contour lines, overlapping and line weight
Ch 7. Drawing Environments
S63. Photo underlay
S64. Site planning
S65. Thumbnail sketching
S66. Non-photo blue, then ink
S67. Sci-fi environment step-by-step
S68. Wrap that angle with a wide-angle lens
S69. Outdoor environment sketch, step-by-step
Ch 8. Drawing Aircraft
S70. Visual research
S71. Drawing from observation
S72. Loose concept sketching
S73. Paper plane perspective grid
S74. Drawing a paper plane
S75. Final airplane drawing
Ch 9. Drawing Wheeled Vehicles
S76. Visual research
S77. Loose concept sketching
S78. Drawing a side view in perspective
S79. Basic body sculpting
S80. Drawing the windshield and greenhouse
S81. Drawing wheels and tires
S82. Drawing a car, step-by-step
S83. Vehicle sketching with a wide-angled lens
Ch 10. Sketching Styles and Mediums

4 10 CORE SKILLS OF DRAWING

The 10 core drawing skills we present are a minimal set of skills needed to express the form of a car with a few 2D curves and then construct perspective 3D curves from them. These essential curves characterize the form of the car, such as the roofline, beltline, and shoulder line, and are collectively called the character line.

Skill 1: Setting the Right Orthogonal Grid. Observing an object through an orthogonal grid and transferring it to another orthogonal grid is an excellent way to draw an object as it appears. The orthogonal grid should have adequate spacing so that it is not too wide or narrow for the form of the object (Figure 2a).

Skill 2: Observing Proportions of Lengths. The characteristics of an object are determined by the relative proportions between the various elements that constitute it. Rather than measuring the absolute size of each element, the proportions should be observed by comparing other elements to a key element, like the wheel of a car. A good orthogonal grid with appropriate spacing makes this comparison easier (Figure 2b).

Skill 3: Observing Negative Spaces. In every visual scene, there are the positive form of an object and the negative space that surrounds it. Focusing on the positive form and the detailed features can distract the observer from grasping the overall form. Conversely, focusing on the negative space makes it easier to identify the silhouette that conveys the overall form. The orthogonal grid can divide the negative space into simpler shapes that are easier to identify and draw (Figure 2c).

Skill 4: Finding the Corresponding 2D Points. Before a curve on a smaller orthogonal grid can be drawn on a larger orthogonal grid, multiple points that the curve passes through should be moved. Every point cross-divides the grid cell it belongs to into particular proportions, and these proportions are maintained even if the size of the orthogonal grid changes. Therefore, a corresponding point can be found by cross-dividing the grid cell of a differently sized grid in the same particular proportions (Figure 2d).

Skill 5: Drawing Lines and Curves. Lines and curves that smoothly pass through multiple desired points should be drawn cleanly in a single stroke. Failing to do so can produce messy overlapping lines and curves that will ruin the drawing. Repeated practice is essential in acquiring good line quality (Figure 2e).

Skill 6: Finding Convergences. Parallel lines in 3D space appear to converge toward a common vanishing point. Expressing this requires drawing several straight lines meeting at a point. However, in many cases of actual drawing, the vanishing point is located outside the drawing. Such requires drawing the line in the correct direction only by relying on intuition, which can be developed through repeated practice (Figure 2f).

Skill 7: Setting the Right Perspective Grid. A perspective drawing should begin with a simple perspective grid consisting of center and floor planes, on which character lines from the side and top profiles can be projected, respectively. An appropriate perspective grid should be selected to show the intended form from the best angle (Figure 2g).

Skill 8: Finding the Center of Rectangles. In both 2D and 3D, the intersection of the two diagonals marks the center of a rectangle. In a perspective drawing where distances are distorted, the center of the rectangle can provide an important depth cue. The center of a rectangle can also be used to divide the rectangle into four smaller ones. Subsequent divisions can make it easier to find corresponding points in the orthogonal and perspective grids (Figure 2h).

Skill 9: Transferring to 3D Plane Curve. To transfer the 2D curve drawn on the orthogonal grid to a 3D curve on the perspective grid, several points on the orthogonal grid through which the plane curve passes are transferred to the perspective grid, and then a curve that smoothly passes through the points is drawn (Figure 2i).

Skill 10: Transferring to 3D Space Curve. Four operations must be performed sequentially to draw an arbitrary 3D space curve and its symmetrical pair. First, draw the side view and top view curves on the orthogonal grids. Second, transfer the side and top view curves to the center and floor planes of the perspective grid. Third, find the intersection points and their symmetry points that occur when extending the center plane curve horizontally and the floor plane curve vertically. Fourth, draw two curves that smoothly pass through the intersection and symmetry points (Figure 2j).

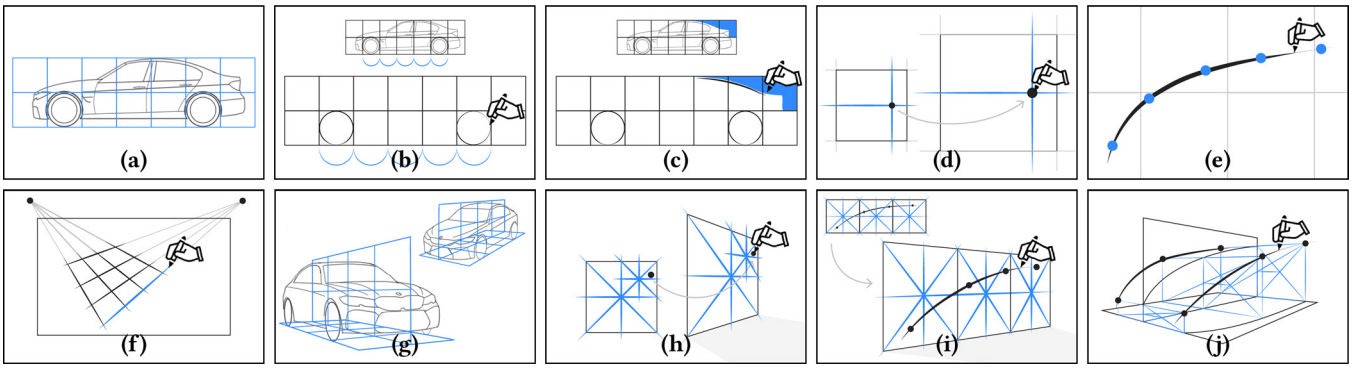

Figure 2: 10 core drawing skills. (a) Skill 1: Setting the Right Orthogonal Grid. (b) Skill 2: Observing Proportions of Lengths. (c) Skill 3: Observing Negative Spaces. (d) Skill 4: Finding the Corresponding 2D Points. (e) Skill 5: Drawing Lines and Curves. (f) Skill 6: Finding Convergences. (g) Skill 7: Setting the Right Perspective Grid. (h) Skill 8: Finding the Center of Rectangles. (i) Skill 9: Transferring to 3D Plane Curve. (j) Skill 10: Transferring to 3D Space Curve.

5 SYSTEM DESIGN

In our novel interaction system, the user follows the friendly guidance of the Tick'n'Draw interaction (Figure 3) during the 5 stages (Figure 1, 4-8), where the user draws the character lines of a nice car in 2D curves and then constructs 3D curves from them. In this natural process of drawing, the user can understand the purpose of the 10 core drawing skills and repeatedly practice them.

5.1 Tick'n'Draw

Some of the 10 core drawing skills require drawing a series of straight lines that pass through a particular point or a pair of points (Skills 4, 8, 9, and 10). These skills may seem complicated at first, but understanding how they work and repeatedly practicing them can make them second nature.

However, beginners are prone to confusion about the order of steps to take, and as failures to draw clean lines accumulate, it can become too messy to continue drawing. Tick'n'Draw is a novel interaction technique that guides the user in what to do in each step while also preventing such an accumulation of failures. Inspired by drawing habits of experts, Tick'n'Draw has the following grammar:

First, Tick. The user specifies one (Figure 3a) or a pair (Figure 3b) of points to pass through with a straight line when one of the skills requires the user to do so. In this case, the system generates a hint suggesting the direction of the line to be drawn by the user (Figure 3c). If the user ticks a meaningless point, the system does not generate a hint and gradually fades the point out.

Then, Draw. The user draws a straight line following the hint. If the line drawn by the user is crooked (Figure 3d) or misses the ticked points (Figure 3e), it is rejected and gradually faded, and the user has to redraw it (Figure 3f). As the user's proficiency increases, the length of the hint can be reduced and the threshold for determining the straightness can be made stricter to appropriately increase the level of difficulty.

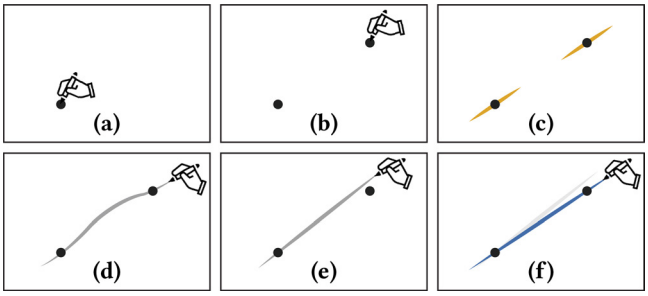

Figure 3: The Tick'n'Draw interaction technique. (a, b) When the user ticks two points, (c) a hint is generated. If the drawn line is (d) not straight enough, or (e) does not pass close to the point, (f) it must be redrawn.

5.2 5 Stages of Car Drawing

The user performs 5 sequential stages below to define the form of the car with 2D character lines in the side and top views, construct 3D curves in perspective using them, and complete a unique car drawing, and in doing so, train the 10 core drawing skills.

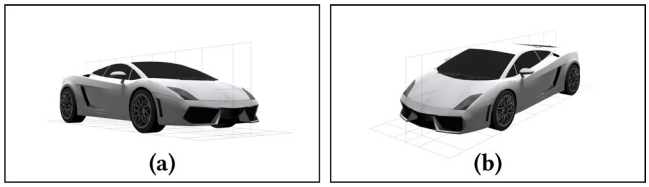

Figure 4: Stage 1: Observation. (a) The user rotates the 3D model of the car and the perspective grid (b) to find the desired angle from which to draw.

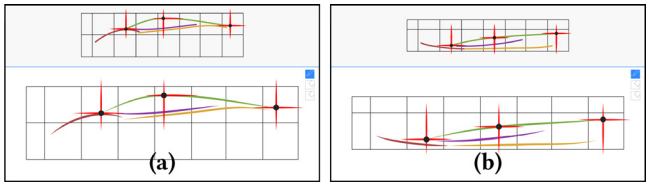

Figure 5: Stage 2: 2D Plane Drawing. With the help of Tick'n'Draw (red), the user observes character lines in (a) the side view and (b) the top view on the upper orthogonal grid and transfers them to the lower orthogonal grid.

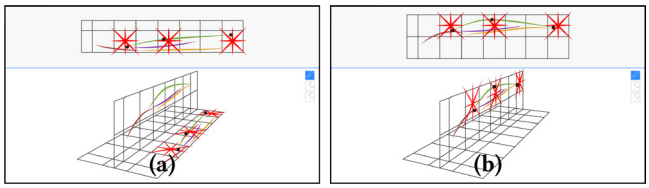

Figure 6: Stage 3: 3D Plane Drawing. With the help of Tick'n'Draw (red), the user transfers the character lines drawn in Stage 2 in (a) the side view and (b) the top view to the perspective grid selected in Stage 1.

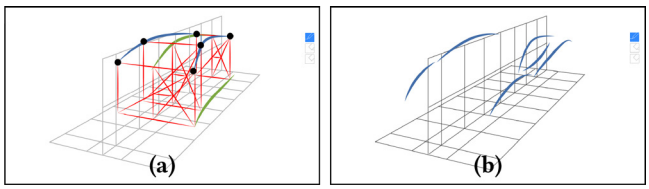

Figure 7: Stage 4: 3D Space Drawing. With the help of Tick'n'Draw (red), (a) the user draws a pair of symmetric 3D space curves of the character line utilizing the center and floor plane curves drawn in Stage 3, and (b) repeats this for all character lines.

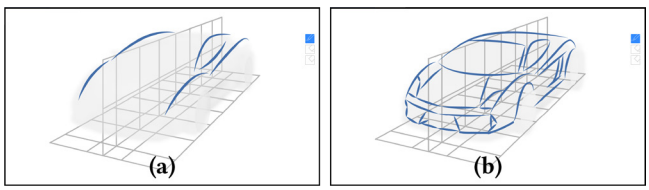

Figure 8: Stage 5: Finishing. (a) On top of the result from Stage 4 and the cloud-like visualization of the rough volume, (b) the user freely fills in fine details and completes the car drawing in his or her unique style.

Stage 1: Observation. The user determines the desired angle from which to draw the car by rotating and observing the 2-point perspective grid visualized on top of the 3D model of the car (Skill 7) (Figure 4).

Stage 2: 2D Plane Drawing. The user observes the 2D character lines in the side and top views on the smaller orthogonal grid displayed at the upper screen and draws them onto the larger orthogonal grid at the lower screen (Figure 5). Doing so entails setting the desired orthogonal grid (Skill 1), observing the relative proportions based on key elements such as wheels (Skill 2), and observing the negative space (Skill 3). A 2D curve that is difficult to transfer through these skills alone may require finding corresponding points through cross splitting (Skill 4) and drawing a curve that smoothly connects the points (Skill 5). Cross splitting, which requires several sequential steps, is performed with the help of Tick'n'Draw (Figure 9).

Stage 3: 3D Plane Drawing. The user utilizes the side and top view curves from Stage 2 to draw 3D planar curves on the center and floor planes of the perspective grid set in Stage 1 (Figure 6). The user draws converging straight lines with the help of Tick'n'Draw (Skill 6), repeats square subdivisions to find corresponding points of the orthogonal grid on the perspective grid (Skill 8), and draws a smooth curve connecting the points (Skill 5) to transfer the curve on the orthogonal grid to the perspective grid (Skill 9).

Stage 4: 3D Space Drawing. The user draws 3D space curves of the character line from the center and floor plane curves drawn in Stage 3 (Figure 7). By drawing many converging lines (Skill 6), the user finds the intersecting points of the horizontal lines drawn from the center plane curves and the vertical lines drawn from the floor plane curves. The user also finds the symmetric points by drawing diagonal lines (Skill 8). Finally, by drawing curves that smoothly connect the intersection and the symmetric points (Skill 5), the curve on the 3D plane is transferred to a curve in the 3D space (Skill 10). Several sequential steps are performed with the help of Tick'n'Draw (Figure 10).

Stage 5: Finishing. The user completes a unique car by freely filling in details using a pen, an eraser, and a stroke eraser. The car is visualized as a cloud-like volume over the minimal space curves drawn by the user in order to stimulate creativity (Figure 8).

6 IMPLEMENTATION

The system was implemented using the Unity 3D game engine and was run on a Wacom Cintiq Pro 24 Touch (DTH-2420) tablet supporting multi-touch and pen input and a Wacom Cintiq Pro Engine (DPM-W1000H) integrated PC module. We selected Lamborghini Gallardo and Tesla Roadster as car models for their well-defined and curvy character lines.

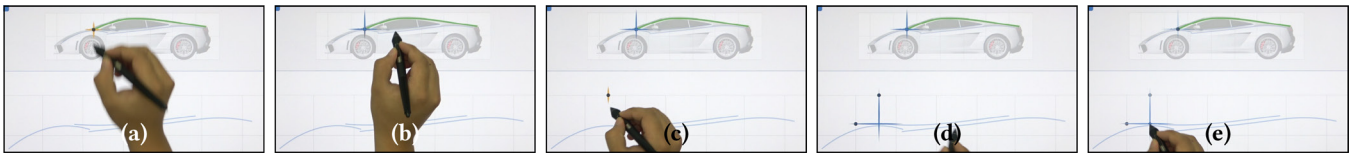

Figure 9: Using Tick'n'Draw in Stage 2: 2D Plane Drawing. (a) Tick a point on the side profile. (b) Draw a crosshair following the hint. (c) Tick a point that divides a cell of the lower orthogonal grid in the same proportions as the upper orthogonal grid. (d) Draw a vertical line following the hint, and then repeat the same process for a horizontal line to make a crosshair. (e) Tick the intersection of the crosshair to display the corresponding point on the upper orthogonal grid.

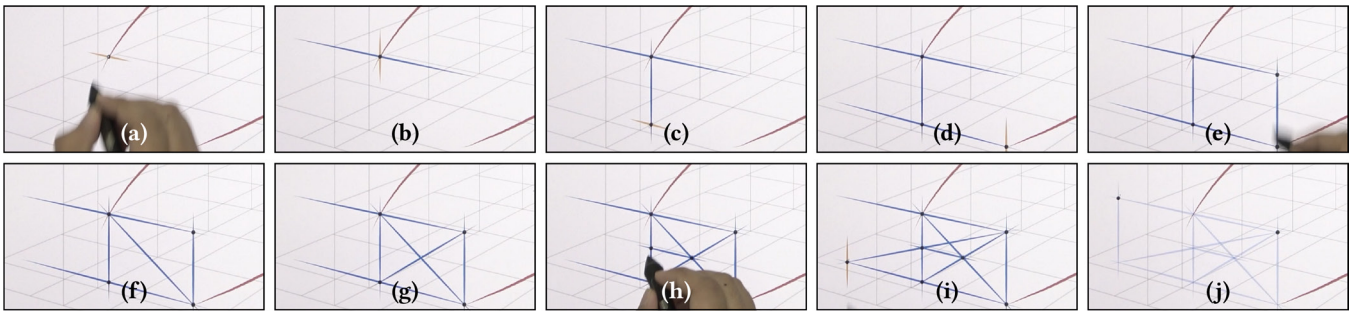

Figure 10: Using Tick'n'Draw in Stage 4: 3D Space Drawing. (a) Tick a point on the side profile. (b) Draw a horizontal line following the hint. (c) After drawing the mirror axis following the hint, tick the intersection of the mirror axis and the floor. (d) After drawing the bottom line following the hint, tick the intersection of the bottom line and the top profile. (e) Draw a vertical line following the hint, and then tick the intersection with the existing horizontal line to find the *combo point* [6]. (f) After ticking the two opposite vertices of the rectangle, draw a diagonal line following the hint. (g) Repeat the same for the other diagonal line. (h) After ticking the intersection of two diagonals, draw a horizontal line following the hint to find the center of the mirror axis. (i) After ticking the center of the mirror axis and the combo point, draw a line following the hint, and tick the intersection of this line and the bottom line. (j) After drawing a vertical line following the hint, tick the intersection between the existing horizontal line and the vertical line to find the symmetric point of the combo point.

7 PILOT TEST

We conducted a pilot test (Figure 11) to check the usability of Tick'n'Draw and improvements in the user's freehand drawings after using our system (Figure 12, 13). 3 students (2 female, 1 male) in their 20s who did not receive professional drawing training participated once a week for 5 weeks with 1.5 hours in each session.

In the first week, participants drew the 3D model of a car on paper without any instructions to show their untrained drawing skills (Figure 12a-c), and then used our system for the first time with a tutorial. During the second to fourth weeks, participants drew one car every week using the system. In the fifth week, another freehand drawing session was held, in which participants used orthogonal and perspective grids on paper to draw the same car model as the one drawn in the first week (Figure 12d-f) and a new car of their own design (Figure 13). From these, we identified three encouraging results:

First, after the 30-minute tutorial, every participant could complete all 5 stages on their own. When they did not know which point to tick, they checked whether a hint was generated by ticking the guessed point rather than asking for help. P1 and P2 said that Tick'n'Draw's unique pattern of usage helped them remember and perform the multi-step drawing process.

Second, when comparing before and after using our system, all participants showed significant improvement in drawing skills (Figure 12 d-f). All the participants proficiently performed the core drawing skills on the grid printed on paper, and as a result, they were able to draw realistic cars compared to when they did not learn the skills. In addition, we observed participants performing ticks repeatedly on paper as if using the system.

Third, the participants could not only draw existing cars but also create entirely new cars from scratch (Figure 13), which gave participants great satisfaction: "I never imagined that I could draw a picture like this (P1)." They also displayed a high level of enthusiasm: "I want to challenge myself with other subjects in this drawing skill (P3)," and "I want to use it on my tablet at home (P2)."

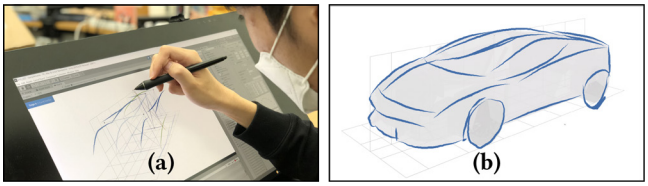

Figure 11: The pilot test was conducted for 5 weeks with 3 participants. During weeks 1-4, (a) participants used our system from Stages 1 to 5 (b) to produce a complete car drawing.

8 CONCLUSION & FUTURE WORK

Drawing is more than just the lines, curves, and shapes that comprise it because it has the potential to enrich the way we observe the world around us and express our thoughts. However, it is unfortunate that many people lose interest in drawing for the rest of their lives because of frustrating experiences during childhood. We designed and implemented our system to give them a chance to become good at drawing.

Using the Tick'n'Draw interaction as if solving one riddle after another, the user can acquire 10 core drawing skills extracted from 2 famous art education books in the natural process of drawing a nice car over 5 stages. We found promising results regarding Tick'n'Draw and the system in a pilot test, where we observed that the abilities developed through the system could be generalized outside the system.

In future work, we aim to develop our system applicable to actual classes and to validate its usefulness. Doing so includes diversifying drawing subjects, customizing learning experiences with adjustments to the level of difficulty and real-time feedback, creating a multi-user environment where students can compete and cooperate, and implementing teacher-friendly features for assessing the learning progress and communicating with the students. We aim to conduct user studies on a classroom scale and publish the results in a follow-up paper.

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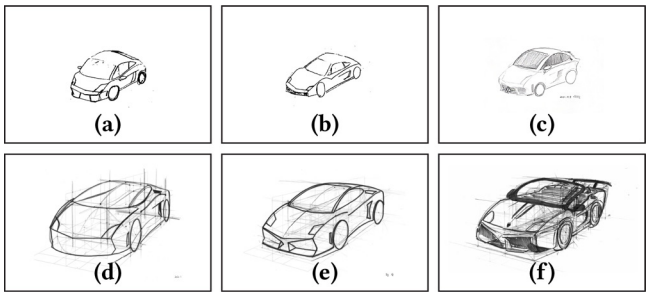

Figure 12: Results of the pilot test. (a-c) Before and (d-f) after using our system 4 times (about 6 hours). Improvements in perspective drawing skills resulted in more realistic drawings.

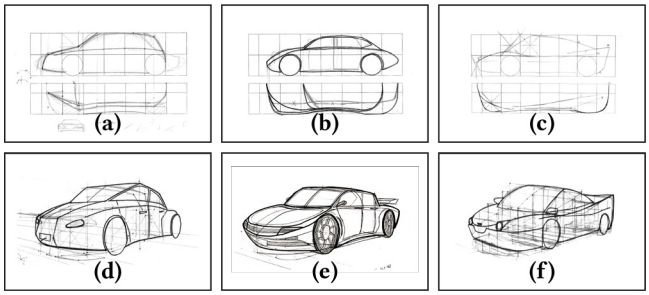

Figure 13: New cars designed by the participants in the fifth week. (a-c) Side and top profiles. (d-f) 3D perspective drawing constructed from the two profiles with the 10 core drawing skills, showing that these skills are generalizable.

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