When Rules Don't Cut It: The Relative Frequency of Inductive and Deductive Language During Real-World Surgical Training

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Abstract

There are two competing predictions for how experts will teach novices. According to one account, general rules and principles are better for equipping learners to perform the complex tasks that are characteristic of many domains of expertise. On the other hand, synthesizing a rule can be challenging for an expert, particularly in real-life environments with complex tasks, and learners may not be able to apply the rule to novel cases. In the present study, we examine a sample of six expert-novice pairs in the context of a robot-assisted surgical procedure in a teaching hospital. The nuances of this domain allow us to examine how an expert's decision to teach inductively or deductively varies systematically across task complexity. We find initial evidence that experts in this domain primarily teach using specific case-by-case examples, as opposed to general rules and principles, regardless of the complexity of the surgical task.

Keywords: expertise; inductive teaching; deductive teaching

Introduction

Psychologists have long disagreed on the relative benefits of inductive and deductive learning. Inductive learning is "learning by example." When shown an example of how to do something, the learner generalizes abstract principles from the example. Deductive learning is when the learner is told the abstract principle directly and expected to apply this principle to future examples (e.g., Winch, 1913).

Past work on inductive and deductive teaching has focused on discerning when each teaching regime is more effective for the learner. Recent work in cognitive psychology suggests that as the complexity of a task increases, verbal rules and instructions (deductive learning) are more effective instructional strategies than teacher demonstrations of the task (Sumers et al., 2023). However, this experiment did not have expert teachers (instead, teachers simply were provided with task information that was concealed from learners), even though real-world teachers are characterized by pedagogical and domain expertise.

Classical accounts of expertise hold that someone is an expert in a particular domain when their actions happen effortlessly and automatically, without the need for careful deliberation (Dreyfus & Dreyfus, 2005). Furthermore, deliberating about one's expert skills may even hinder performance (Beilock & Carr, 2001). Experts who are tasked with teaching novices often struggle to convey what they are doing and how they are doing it. This may be why novices struggle to acquire the relevant perceptual contrasts through discussion with experts, for whom the diagnostic features of a task appear obvious or even trivial (Bransford et al., 1989).

Taking stock, we identify two competing predictions: (1) Teachers may choose to disseminate knowledge about complex tasks using rules over specific examples; or alternatively, (2) Teachers may choose to employ inductive modes of teaching complex tasks, pointing out specific details of an example rather than stating a general rule. By one account, as task complexity increases, teachers will increase their use of generalizable rules (favoring deductive learning; Sumers et al., 2023; Moskvichev, Tikhonov, & Steyvers, 2023), but by another account, experts will have difficulty articulating general rules as task complexity increases (Beilock & Carr, 2001), and will instead emphasize specifics of the current case. Instead of determining which teaching mode is more effective for the learner, we will explore how instructional language varies in a real-world learning environment with varying task complexity.

In the current study, we examine the language used when experts teach novices *in situ*, in an established training environment: an operating room in a teaching hospital. In doing so, the current study is a direct response to recent calls for cognitive science to situate its methods and theories not only in contrived computerized tasks, but also in real world domains of societal importance (Ibanez, 2022; Lewis, 2022). Specifically, we examine how teachers instruct students in performing a common and typified surgical procedure, robot assisted radical prostatectomy (RARP). In this procedure, a teacher (the attending surgeon) and a student (the surgical resident) will jointly perform the operation using two tethered da Vinci robot consoles (Intuitive Surgical, Inc.; Sunnyvale, CA), trading control of the surgical robot back and forth while discussing the procedure (see Figure 1). Because these consoles are physically separate from one another (and from the patient, the nurses, and the anesthesiologist), there are microphones in each console, which amplify the dialogue

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between the teacher and the student and broadcast it through the operating room. This audio feed, along with the video feed from the robot's camera probe, are routinely recorded for the resident's later review. In the current study, we analyze these case recordings to measure how the language during surgical training differs between surgical steps that are of high and low complexity.

Figure 1: da Vinci surgical system control consoles, with a surgical resident (left) and attending surgeon (right).

Method

The current study was exploratory and not preregistered, and it was approved by the Indiana University Bloomington institutional review board. Anonymized transcripts of the recordings are openly available at https://osf.io/gx6ha/ (Gatto et al., 2025).

Participants

All attending urologic surgeons who performed RARP as part of their practice and all urology residents and fellows at a single academic hospital system in a metropolitan area in the midwestern U.S. were invited to consent. By consenting, they allowed our analysis of case recordings, and further, they agreed to respond to survey questionnaires about the cases. 11 surgeons and 16 trainees (13 residents, 3 fellows) provided consent. Because these surgeries were being performed in teaching hospitals associated with a university medical school, all patients had previously provided explicit agreement that their cases may be recorded and used for teaching and research purposes.

Among the surgeons and residents who provided consent, the current study examines six case recordings, which include four different surgeons and six different medical residents (one of the cases had two residents, and one surgeon-resident pair operated together twice).

Surgeons were all male, and they were White (n = 3) and Asian (n = 1), with ages ranging from 44 to 68 (M = 55.8 years). Surgeons had 9 to 27 years in practice.

Residents were Asian (n = 3), White (n = 1), Native Hawaiian or Pacific Islander (n = 1), and Other (n = 1), from 26 to 36 years of age. Trainees were in their fifth year of residency or fellowship on average (range 2 – 7 years). Six residents identified as male and one as female.

Setting and Task

Prostate cancer is one of the most common cancers diagnosed in men in the United States, with the American Cancer Society predicting over 313,000 new cases of prostate cancer in 2025 (National Cancer Institute, 2025). Robot-assisted radical prostatectomy (RARP), a minimally invasive surgical technique for removing the prostate, is one of the most common treatments of localized prostate cancer, with up to 40% of men electing for RARP for newly diagnosed prostate cancer (Westerman, 2024). At the academic medical center where this study was performed, over 500 RARPs were performed in 2024.

The oncologic success of RARP is favorable with progression of disease only occurring in 10% of patients and only 2% of patients dying of prostate cancer after RARP (Hamdy et al., 2023). However, RARP can have a significant effect on quality of life with the risk of urinary incontinence and erectile dysfunction postoperatively. Surgeon experience and surgical technique have been shown to affect both oncologic and quality of life outcomes after RARP (Ficcara et al., 2012; Ju et al., 2021).

Urology residents spend 5-6 years in residency training to become independent urologists. By the time they graduate, urology residents are expected to be able to perform most urologic procedures, including RARP, independently. The Accreditation Council for Graduate Medical Education (ACGME) requires a minimum of 30 prostatectomies to graduate from urology residency. However, the true learning curve for RARP is poorly understood, with studies suggesting that at least 50 if not up to 700 cases are required for outcomes to plateau (Ryan et al., 2022; Sooriakumaran et al., 2011). There is concern that urology residents may graduate without being able to perform RARP independently (Cruz et al., 2020). Therefore, the one-on-one education between the attending surgeon and urology trainee in the operating room is essential to optimize this learning curve.

The process of learning how to perform RARP independently has numerous components. Not only must a urology trainee learn the basics, such as detailed pelvic anatomy, potential variations on the anatomy, and the steps of a prostatectomy, but they must also learn how to properly operate the surgical robot, troubleshoot during complex cases, and they must understand the nuances of each individual patient case to tailor the procedure to the patient's specific cancer.

High and Low Complexity Focal Steps in RARP

There are 10 discrete steps in a RARP procedure (Challacombe, Cathcart, and Kirby, 2024), which can be performed in variable order depending on the surgeon's preference. One of these steps (nerve sparing) can be skipped at the surgeon's discretion. On average the procedure takes 3-4 hours to complete. The 10 steps in RARP naturally vary in their degree of complexity. For the current study, our goal is to contrast the instructional language used by the attending surgeon between high and low complexity steps of the procedure. To identify these focal steps, we sent an online

Table 1: Examples of inductive and deductive utterances, at different surgical steps

Step (order in procedure)	Complexity	Teaching Type	Example Utterance
Dropping the bladder (1 or 3)	Low	Inductive	There's something there that's arterial.
		Deductive	Artery's the thing that beats.
Nerve sparing (5)	High	Inductive	Extra push down here.
		Deductive	Those blood vessels that sit on the lateral part of the press, those tend to be outside of the fascia.
Urethra division (8)	Low	Inductive	What I do is go a bit posterior like this.
		Deductive	Not an uncommon place to leave a bit of tissue
Vesicourethral anastomosis (9)	High	Inductive	And then your flat side down rotate rotate rotate rotate rotate rotate rotate rotate rotate.
		Deductive	See, the key is to get the whole thickness of the urethra, right?

questionnaire to all consenting participants, asking them to rate the complexity of each of the ten steps of RARP using visual analogue scales (de Leeuw et al., 2023; Kinley, 2022). Visual analogue scales yield ordinal rankings for complexity without introducing bias towards middle or endpoints of the scale.

Of the 27 consenting participants, 22 responded to this questionnaire. Based on their responses, we chose the following focal steps: dropping the bladder (DTB; low complexity), vesicourethral anastomosis (VA; high complexity), nerve sparing (NS; high complexity), and urethra division (UD; low complexity). A key feature of these selected focal steps is that their order in the surgery is balanced across high/low complexities (see Table 1), preventing the possibility that any difference in the instructional language used during the step is caused by its ordinal position in the 4-hour long procedure. Dropping the bladder and nerve sparing occur earlier in procedure than urethra division and vesicourethral anastomosis, regardless of the surgeon's preferred method of approach.

While these four steps are common in RARP, individual procedures may deviate from these steps in certain circumstances. In particular, nerve sparing, which is done to preserve a patient's sexual functioning post-operation, is not performed in all RARPs. All the other focal steps are routinely performed during most RARP techniques.

Procedure

We stored case recordings on a secure server. A faculty member in the urology department assigned timestamps to the different videos, determining when each step in the surgery began and ended. We extracted segments of the videos in which the four focal steps took place, and we used Adobe Premiere Pro (version 24.0) to automatically transcribe the auditory stream from each segment into text. Finally, we manually reviewed and edited each transcript to remove any identifiable information, to assign the transcribed text to the correct speaker (surgeon or resident), and to ensure the accuracy of the transcripts.

Analysis

We parsed the transcripts into utterances, using pauses and breaks in punctuation to indicate that one utterance had ended and another had begun (Charmaz, 2006). There were 1,054 utterances spoken by the attending surgeons in total across the four focal steps from the six case recordings, about the case at hand. Then, two members of the research team worked independently to classify each utterance from the attending surgeons as inductive talk, deductive talk, or irrelevant talk. Raters had identical classifications on 80.6% of the utterances, corresponding to Cohen's $\kappa = 0.586$, $p < .001$ on first pass.

Of the 204 utterances raters disagreed on, 30 of them were incomplete or unfinished thoughts. During discussion of classifications, raters came to the agreement to only code for inductive and deductive teaching when a thought was complete, even if the part available to them made it seem that the attending surgeon was about to say something that should be classified in one of the relevant categories. Additionally, 24 of the ambiguous utterances seemed to be examples of brief feedback on how the resident was operating (e.g., "Good call" or "No"). However, we agreed to classify these utterances as neither inductive nor deductive. We made both decisions to avoid inferring beyond what was said.

Raters also discussed all additional utterances they disagreed on until reaching an agreement on how to classify them into the three categories. The final analysis has complete agreement on the labels attached to each utterance.

We opted against running statistical tests for numerous reasons. The current study uses a pilot sample of six cases, and thus, statistical tests would be underpowered. More data collection is planned in the future. We draw coarse qualitative comparisons between inductive and deductive modes of teaching with the goal of forming an intuition for how these teaching modes might look in a naturalistic environment, and to evaluate their prevalence outside of the laboratory.

Codes

Inductive utterances were specific to the case at hand. These utterances included some of the following sub-types: (1) Pointing out basic anatomy; (2) Narrating one's thoughts; and (3) Commanding the resident on how to steer the robot.

On the other hand, deductive utterances were rules of thumb for the residents to use later. These utterances included some of the following sub-types: (1) Wisdom about being a surgeon in general; (2) Generalizations about the procedure; and (3) Statements about goals, causal relationships, and/or consequences. For examples of deductive and inductive utterances at each of the four focal steps, see Table 1.

Results

Out of 1,054 utterances across the four focal steps from six case recordings, 735 of these utterances were able to be coded as inductive or deductive.

Step Characteristics

We examined four focal steps for six operations. Nerve sparing was skipped in two cases. Additionally, during Case 2, the recording device malfunctioned during DTB. This left 21 video clips to analyze in total.

The shortest step across procedures was the urethra division (*M* = 1:51), while the longest step was vesicourethral anastomosis *(M* = 26:44*)*. For a more complete breakdown of the time spent on each step for each case, see Table 2.

Case	DTB (lo)	NS (hi)	UD (lo)	VA (hi)	Total
1	16:45	14:02	4:40	20:27	55:54
2	*Missed*	*Skipped*	1:28	40:35	42:03
3	11:35	16:46	2:03	37:32	67:56
4	16:03	6:57	1:15	12:58	37:13
5	16:03	10:34	1:08	32:24	60:09
6	9:22	*Skipped*	0:33	15:56	25:51
Mean	13:58	12:05	1:51	26:44	54:38

Table 2: The time spent (in minutes and seconds) on each step during each surgical case.

The number of attending utterances varied by case. The attending surgeon in Case 5 was the most talkative during the four focal steps (*n* = 278 teaching utterances; roughly one utterance every 13 seconds). Additionally, attendings spoke the most teaching utterances during the vesicourethral anastomosis (*mean* = 87.7; roughly one utterance every 18.3 seconds). Note that the attending surgeon did not speak at all during Case 1, DTB. For the total teaching utterances in each case, and for each step refer to Table 3.

There were modestly more utterances per minute by the attending surgeon for low-complexity steps (*M* = 0.53 per minute) than for high-complexity steps *(M* = 0.38 per minute*)*. It is unclear whether this is a statistically credible difference at the current sample size. Other factors may also influence the amount of talk, such as the resident's level of experience – some of the more experienced residents were able to operate on their own, without much comment from attending surgeons.

Case	DTB (lo)	NS (hi)	UD (lo)	VA (hi)	Total
1	*0*	6	3	83	92
2	*Missed*	*Skipped*	2	77	79
3	11	21	2	116	150
4	34	13	4	16	67
5	54	16	4	204	278
6	29	*Skipped*	10	30	69
Mean	25.6	14	4.2	87.7	131.4

Table 3: Number of utterances at each step for each case. The horizontal totals show inductive or deductive utterances for each step, across cases, while vertical totals show them per case.

To account for the different frequencies of utterances for the six cases, we examine the relative proportion of utterance types for the subsequent analysis.

Inductive and Deductive Utterances

A core goal of this research is to ascertain whether the complexity of a task affects the linguistic approach an attending surgeon uses to teach the task. One might expect that complicated tasks demand rule-based teaching approaches, in light of results from laboratory studies. Despite this, we found that inductive teaching utterances

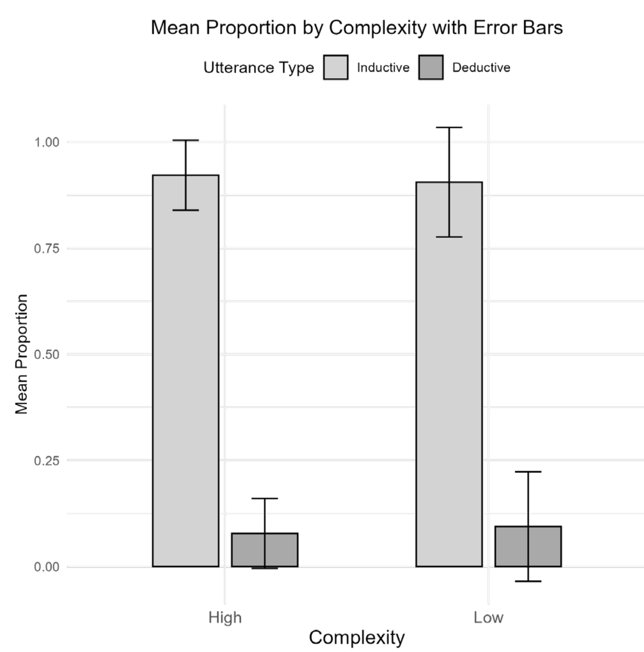

Figure 2: The mean proportions of inductive and deductive utterances, for high- and low-complexity surgical steps. The error bars represent the standard deviation.

vastly outnumbered deductive utterances, irrespective of the task complexity according to surgeon reports (M = 0.92 inductive for high-complexity steps; M = 0.91 inductive for low-complexity steps). Furthermore, the proportions of deductive utterances in the low- and high-complexity tasks appear to be indistinguishable (M = 0.08 deductive for low-complexity steps; M = 0.09 deductive for low-complexity steps).

Utterance Lengths

We take the length of an utterance to be the total number of words from start to finish. Deductive talk was used much less frequently than inductive talk, irrespective of task complexity according to the surgeons. Upon making this observation, we decided to examine if the length of the utterance varied depending on the type of utterance.

We found that deductive utterances (M = 9.6, SD = 5.0) were nearly twice as long as inductive utterances on average (M = 5.1, SD = 3.3) in terms of the number of words used to complete the utterance.

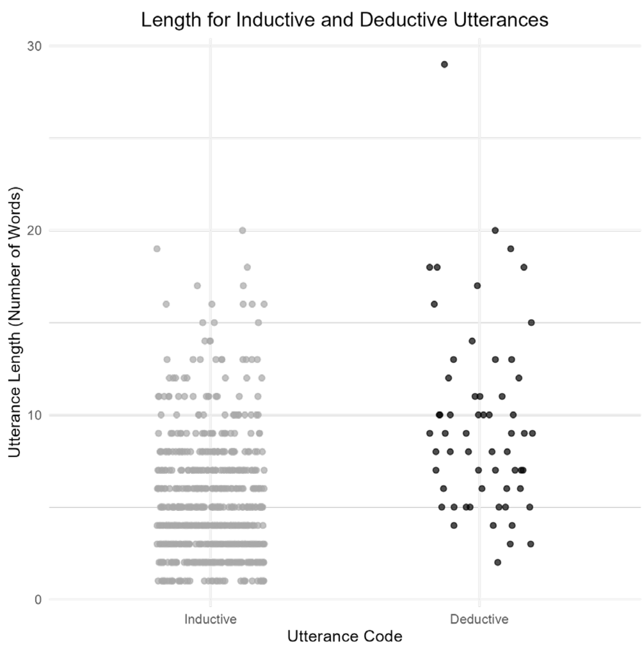

Figure 3: A scatterplot showing each utterance length for inductive and deductive samples. The points are jittered horizontally for clarity.

Transitions Between Teaching Modes

Next, we investigate the use of inductive and deductive teaching in time. To preserve some information about the timing of the utterances, we included other talk, such as incomplete utterances, filler words, workplace gossip, or other talk that was not educationally relevant to the immediate task (e.g., learning to perform the current surgical step). Within each case and step, we computed the transition probabilities for each combination of states of talk (deductive, inductive, and other). Then, we aggregated over low- and high-complexity conditions to get overall Markov process models for each complexity condition. In Figures 5 and 6, the line weight of each arrow corresponds to the magnitude to the transition probability.

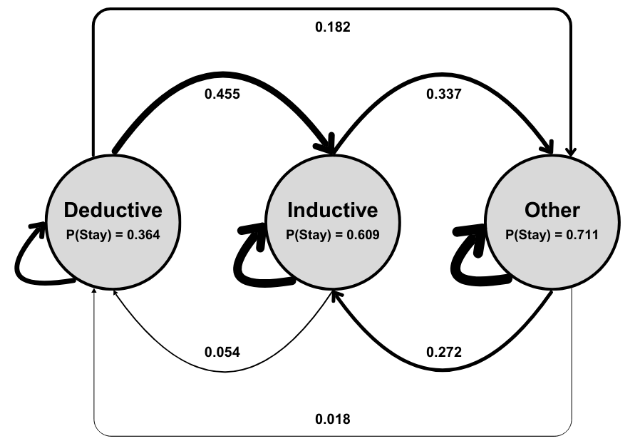

Figure 5: Transition probabilities for low-complexity steps.

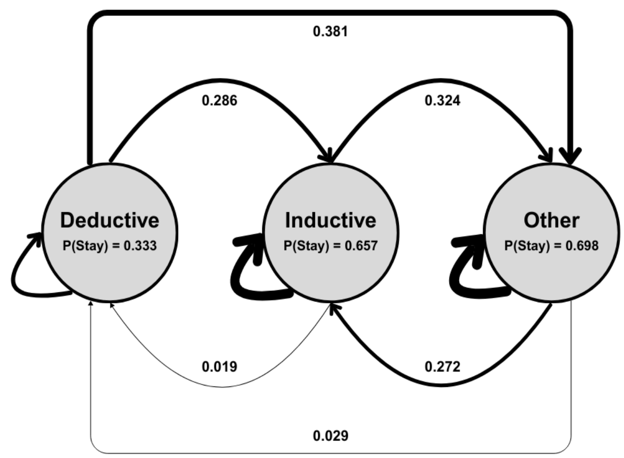

Figure 6: Transition probabilities for high-complexity steps.

A visual inspection of these process models suggests that attending surgeons exhibit strikingly similar patterns of talk during low- and high-complexity steps. Furthermore, irrespective of complexity, it was highly unlikely for an attending surgeon to remain in the deductive teaching state, or to transition into that state from another. This is inconsistent with the notion that high-complexity situations require teaching using rules, more so than low-complexity situations. Additional data collection is needed in order to draw robust inferences about these patterns over time.

Discussion

We performed an analysis of instructional speech during real-life surgical training cases at a teaching hospital, where attending surgeons (experts) and surgical residents (students) collaboratively performed the operations. We found that moments of inductive teaching vastly outnumbered deductive modes regardless of the task complexity, in contrast to prior work which had predicted that deductive rules should be more prevalent with increasing task complexity. Data collection will continue, allowing us to perform well-powered statistical tests. However, the overwhelming pattern of results makes us think that this pattern will generalize to new cases. Despite our best efforts, we were unable to find other studies on the relative frequency of inductive and deductive language during teaching.

Work from Sumers et al. (2023) indicated that deductive statements would be more prevalent in high-complexity tasks than inductive statements. The researchers used a simple task in which participants earned points by driving an avatar into colorful shapes. Unlike our study, there were no genuine experts at this task. The teacher merely had information that the novice did not have. The artificiality of this hidden knowledge means that the teachers in the prior study did not face the same constraints as true experts, who according to Beilock and Carr (2001), find it challenging to reduce their expert actions into concrete rules. When expertise is inherent to the task, as it is in many learning environments, rule-articulation may become unwieldy and impractical for the expert. Considering that we did not measure other prevalent modes of inductive teaching, namely verbal feedback and demonstration, our analysis likely underestimates the prevalence of inductive teaching — and yet, inductive utterances still vastly outnumbered deductive utterances across both complexity conditions.

In the future, we will perform analyses that respect the temporal dynamics of the surgeons' language, akin to Karmazyn-Raz and Smith's (2023) work in developmental contexts. Furthermore, we will continue to understand the reasons why one might switch from an inductive to deductive teaching mode (and vice versa) by closely examining the situations in which these transitions occur. One might expect that the frequency of rule-administration from attendings might increase when residents make errors, to quickly redirect the resident and prevent the same error from occurring in future operations.

An additional consideration of this work is that we used talk and utterances as a measurement of inductive and deductive teaching. There are other teaching modes that could be easily quantified during RARP, such as whether demonstration uses observation or allows active learning by the resident. In RARP, the surgeon can provide control of the robot to the resident, and additional research might examine how the change in control affects instructional language used by the surgeon. Even so, considering action-based approaches in our analysis may further emphasize the frequency of inductive teaching styles during surgery.

In the same vein, we coded all instances of one- or two-word feedback for the residents as neither inductive nor deductive, because these utterances were too short to make clear classifications. Furthermore, we did not want to overinflate our proportions for inductive teaching or make inferences about what these brief utterances ("Good" or "Yeah") were referring to. However, it is worth noting that allowing the resident to operate the robot while providing feedback is another significant inductive approach to teaching.

For this study, we constrained our analyses to teaching moments directly relevant to the surgical task at hand. Even so, part of the milieu in the operating room is workplace gossip, anecdotes, and discussion about other cases (Nieboer et al., 2019; Roberts et al., 2012). All of these were prevalent in our sample. While not related to the immediate task, and thus not considered for coding in the present work, we maintain that these linguistic encounters serve the potentially valuable role of disseminating practical knowledge to the residents. Future work will explicate practical wisdom as a facet of inductive teaching in the operating room.

One might argue that the task of RARP is equally contrived as those teaching-learning tasks set up in a laboratory. Perhaps RARP is unlike other environments where novices regularly learn from close interaction with experts, and unlike other sorts of learning tasks where inductive and deductive teaching are scientifically studied. Even so, we chose to examine RARP knowing that the teachers have genuine expertise in the task; that the learners have a vested interest in learning to do the task; that this learning task is consequential to both teachers and learners; and that the task procedure is stereotyped and easily recorded. These features make RARP well positioned to inform future research on teaching in the wild.

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