Moving Beyond "Does Active Learning Work?" with the Engineering Learning Observation Protocol (ELCOT)

Dr. Megan Sanders, Colorado School of Mines

Megan Sanders is the Senior Assessment Associate at the Trefny Innovative Instruction Center at the Colorado School of Mines. Before joining Mines, Megan worked at the Eberly Center for Teaching Excellence and Instructional Innovation at Carnegie Mellon University, where her role focused on supporting instructors in conducting research about student outcomes in their courses. Megan's disciplinary background is in educational psychology. She earned her PhD from the Ohio State University, and her research focused on the idea of relevance in higher education—how we define it, how students perceive it, and how to measure it—an interest that continues to inform her work.

Dr. Sam Spiegel, Colorado School of Mines

Dr. Spiegel is the Director of the Trefny Innovative Instruction Center at the Colorado School of Mines. He previously served as Chair of the Disciplinary Literacy in Science Team at the Institute for Learning (IFL) and Associate Director of Outreach and Development for the Swanson School of Engineering's Engineering Education Research Center at the University of Pittsburgh. Prior to joining the University of Pittsburgh, he was a science educator at Biological Sciences Curriculum Study (BSCS). Dr. Spiegel also served as Director of Research & Development for a multimedia development company and as founding Director of the Center for Integrating Research & Learning (CIRL) at the National High Magnetic Field Laboratory, Florida State University. Under Dr. Spiegel's leadership, the CIRL matured into a thriving Center recognized as one of the leading National Science Foundation Laboratories for activities to promote science, mathematics, and technology (STEM) education. While at Florida State University, Dr. Spiegel also directed an award winning teacher enhancement program for middle grades science teachers, entitled Science For Early Adolescence Teachers (Science FEAT).

His extensive background in science education includes experiences as both a middle school and high school science teacher, teaching science at elementary through graduate level, developing formative assessment instruments, teaching undergraduate and graduate courses in science and science education, working with high-risk youth in alternative education centers, working in science museums, designing and facilitating online courses, multimedia curriculum development, and leading and researching professional learning for educators. The Association for the Education of Teachers of Science (AETS) honored Dr. Spiegel for his efforts in teacher education with the Innovation in Teaching Science Teachers award (1997).

Dr. Spiegel's current efforts focus on educational reform and in the innovation of teaching and learning resources and practices.

Dr. Jennifer Zoltners Sherer, University of Pittsburgh

Jennifer Zoltners Sherer is a Research Associate at the University of Pittsburgh's Learning Research & Development Center. Her work focuses on developmental evaluation, initiation and development of networked improvement communities (NIC), and improving STEM teaching and learning. Her research interests include distributed leadership, organizational change, and improving teaching and learning through tool design and implementation, professional development, reform initiatives, and curriculum. Prior to receiving her Ph.D. in Learning Sciences from Northwestern University, she was a teacher in Oregon.

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Introduction

This Evidence-based Practice Paper responds to the call for "a more nuanced approach to active learning" (Streveler & Menekse, 2017, p. 189), required because simply asking "does active learning work?" no longer moves the field of engineering education forward. Extensive work reviewed in two meta-analyses (Freeman et al., 2014; Prince, 2004) has definitively answered that question: yes. Instead, Steveler and Menekse (2017) suggest it is necessary to pay attention to the particular context, studying which active learning practices best support specific learning outcomes and student populations. The question is no longer "does active learning work?" but "what kind of active learning works best for which learning outcomes, which populations of students, and in what circumstances?"

Consistent with this call, we facilitate a month-long faculty professional learning program on Engineering Learning, an intentional design process that helps faculty focus not simply on implementing active learning, but more specifically on appropriately aligning instructional strategies with learning outcomes and assessments (Wiggins & McTighe, 2005). To detect changes in faculty teaching practice as a result of attending the Engineering Learning Intensive, we developed the Engineering Learning Classroom Observation Tool (ELCOT; Tolnay, Spiegel, & Sherer, 2017), a classroom observation tool designed to capture teacher activity, student activity, and levels of active learning. In this paper, we describe the context and theoretical grounding for the ELCOT, compare it with existing classroom observation protocols, and, using case studies of two faculty members, illustrate the potential of the tool to enhance our understanding of active learning.

Design of the ELCOT

Engineering Learning is a design and implementation model that was developed to guide and inform engineering faculty as they work on their courses. The broad intent is to shift the way faculty think about and talk about courses, moving them from a perspective and concern about "covering" content to one focused on learning and intentional outcomes. A month-long intensive learning program (Engineering Learning Intensive) was developed to accelerate the up-take of the Engineering Learning model. This initiative was funded to stimulate systemic changes and required significant funding. We wanted to monitor and evaluate the program in terms of classroom practices and student outcomes. We developed the ELCOT to assess classroom interactions and practices.

The Engineering Learning Intensive drove the development of the ELCOT, and both the program and the protocol share similar theoretical groundings, including backward design (Wiggins & McTighe, 2005), Webb's depth of knowledge (2007), and Principles of Learning (Resnick, 1999). These frameworks represent some of the material faculty interact with during the Intensive and, as such, guide what aspects of the classroom observers attend to when using the ELCOT. The categories observers code include student organization, student talk, student activity, and instructor activity, each of which includes subcodes (see Appendix A). The student activity codes are grouped into levels according to Webb's depth of knowledge (2007; see Appendix C for operational definitions). Level 1 tasks require low cognitive engagement, with tasks such as *taking notes*, *following procedures*, or *recalling information*. Level 2 activities require some low-level processing on the part of the student, reflecting tasks such as *summarizing information*, *interpreting graphs*, and *collecting data*. Level 3 tasks generally require students to apply content and skills they have learned to complete activities such as *analyzing data*, *explaining using course concepts*, and *revising work*. Last, Level 4 tasks such as *synthesizing*, *designing*, and *reflecting on one's own learning* require the highest level of cognitive engagement. In addition to these nuances of student activity, the protocol also captures the instructor's stated learning objectives for the class and the observer's judgment of the alignment between the objectives and the classroom activities.

The ELCOT and Existing Observation Protocol

An observation tool drives what you see and record. The tool should be based on what you want to see and hear and should be limited to observable behaviors rather than interpretations. The tool should pinpoint, differentiate, and characterize the interactions and practices of the students and faculty as together they construct the classroom experience.

When compared to existing classroom observation protocols, such as the COPUS (Smith et al., 2013) and the RTOP (Sawada et al., 2002), the ELCOT highlights complexities in the implementation of active learning that are not well captured in other protocols. COPUS was designed to asses increased student engagement in large lecture courses. The RTOP is closer to our desired foci by exploring student-centered, engaged learning practice, but did not have the sensitivity or interaction measures we desired. For our purposes, the ELCOT was better aligned with the aspects of the classroom we wanted to pay attention to: namely, the types of interactions happening in the class, the cognitive demand of the tasks being done by students, and the instructor practices as they align with the Engineering Learning model. Additionally, the ELCOT helps observers attend to the broader *alignment* between classroom activities and learning objectives, rather than the presence or absence of active learning alone. This allows individual faculty to identify opportunities for improvement in alignment. At the same time, the whole data set reflects patterns of need that the Center can support.

Objectives of Present Study

To illustrate how the ELCOT provides a more complex picture of teaching practices, we describe case studies of two faculty members who participated in the Engineering Learning Intensive. In one case, the ELCOT reaches a similar conclusion as other observation protocols likely would about the effectiveness of the class. In the other case, the ELCOT detects nuances that other protocols would likely miss, ultimately drawing a different conclusion about the class's effectiveness. Our goal in presenting these cases is to show how the ELCOT, by attending to the specific characteristics and alignment of the learning activities and the intended learning outcomes, helps us move beyond asking whether or not active learning works.

Method

The two case studies presented here are drawn from a larger sample of 93 classroom observations of 54 different faculty instructors during the Spring 2017 and Fall 2017 semesters. Some faculty instructors were observed during both semesters. Observations were conducted during the middle of the semester to allow sufficient time for classroom routines to be established, without also getting too close to the end of the semester when the focus shifts to finals and project completion. The ELCOT tool tracks the interactions in two-minute intervals, allowing categorization by time as well as activity.

Only the first 50 minutes of each class were included in the data because the vast majority of courses on campus are offered in a 50-minute format and because in past observations, we have found that the patterns of classroom activity tend to repeat over the class period. The data were aggregated by course in two ways. For variables that represented discrete events, such as a student asking a question or the instructor posing a task, the number of occurrences was summed across the first 50 minutes of the observation. For variables that represented activities that occur across time, such as the instructor *demonstrating how to solve a problem* or students working to *design a solution*, aggregates were represented as proportions of class time during which the activity occurred. To calculate this proportion, the number of two-minute intervals in which the activity occurred were summed and divided by 25, the total number of two-minute intervals in the first 50 minutes of the class. Because multiple activities can co-occur in the same two-minute interval—an instructor can alternate between *using a visual aid* and *lecturing*, or an activity might require students to both *collect data* and *interpret models*—the class time spent on various activities may sum to more than the total amount of class time.

Although this is true of each individual activity code, a set of four variables (L1 Activity, L2 Activity, L3 Activity, and L4 Activity) was created to capture the amount of time students spent engaged at each of the four levels of cognitive demand (Webb, 2007). These variables represent the number of two-minute intervals in which students engaged in any of the specific activities at each level, but do not "double count" if more than one type of activity that level occurred during the interval. For example, if students were both *following procedure* and *calculating* during a two-minute interval, that interval would be coded as a single instance of L1 Activity. Thus, these variables characterize student activity during a class meeting at a broader level than individual codes.

The aggregated data by course were used to select the two case studies. First, the set of observations was narrowed to those in which the instructor communicated the learning outcomes to students explicitly and in which the task aligned with the learning outcomes (see Appendix A). From among this subset, we then looked for differences in the pattern of how class time was spent. In particular, we identified courses in which a large proportion of class time was spent in lecture, as well as courses in which a relatively small proportion of class time was spent in lecture. We highlight two case studies that illustrate the power of the ELCOT to shift our focus from active learning alone to the appropriate alignment between particular pedagogical strategies and learning outcomes.

Results

Case Study 1 – Active Learning-Driven Class Meeting

This class meeting was part of an upper-level Civil Engineering course taught by an assistant professor who participated in the second offering of the Engineering Learning Intensive. There were 24 students in the Civil Engineering course (33% women and 66% men), and the majority were seniors (92%; the remaining 8% were juniors) and all but one were Civil Engineering majors. Thus, this was a fairly specialized majors course taught to advanced students. The instructor indicated that the learning outcomes for the class meeting being observed were for students to "apply the concepts of concrete mix design in groups and determine the concrete constituent's proportions." When framed in terms of Webb's depth of knowledge (2007), these learning outcomes appear to reflect Level 3 activities, such as analyzing data and using concepts to solve.

Examining the pattern of instructor and student activity during the observed class (see Table 1) suggests that these activities were both active and well-aligned with the learning outcomes. For example, the instructor only spent a small portion of class time lecturing (20%) and addressing students as a whole group (24%). Instead, he directed students to work in small groups, where they spent the majority of class time (76%). The instructor assigned five group tasks during the observation and spend his time monitoring students' work (56%) and interacting with small groups (56%). Students, in turn, spent most of class discussing with their peers (68%) and engaging in Level 1 activities (64%), such as calculating and following procedures, and Level 3 activities (68%), such as analyzing data and using concepts to solve.

Table 1. Instructor and Student Activity

INSTRUCTOR CODES		
	Case 1 (AL)	**Case 2 (Lecture)**
Instructor Activity		
Lecturing	20%	92%
Demonstrating problem solving	0%	92%
Modeling thinking	0%	72%
Monitoring work	56%	0%
Interacting with small group	56%	0%
Building community or rapport	0%	16%
Administration	20%	12%
Not engaged with students	16%	0%
Organization of Students		
Individual	0%	4%
Small Group	76%	0%
Large Whole	24%	100%
Individual Task	0	5
Group Task	5	0
Instructor Questions		
Recall (L1)	0	15
Summarize, compare (L2)	1	7
Explain (L3)	0	0
Extending student thinking (L4)	0	0
Answers student question	1	8

STUDENT CODES		
	Case 1 (AL)	**Case 2 (Lecture)**
Student Activity		
Listening passively	20%	4%
Discussion	68%	0%
L1 Activity	64%	88%
L2 Activity	0%	0%
L3 Activity	68%	0%
L4 Activity	0%	0%
Student Questions		
Administrative Question	0	0
Clarifying Question	1	4
Conceptual Question	0	10
Student Answers		
Provides answer (closed)	0	13
Explains/elaborates (open)	1	1

If this class meeting were observed using a different observation protocol that focuses on active learning alone, it would likely be rated as very active: students spent the majority of class time in small groups, discussing with peers, and cognitively engaged in an authentic task. By definition of being characterized by active learning, this class would likely also be considered pedagogically effective. When considered in terms of ELCOT, this class meeting would also be considered active and effective, but for additional reasons. Not only were students cognitively engaged during the class, but the types of activities they engaged in were well-aligned to the learning outcomes for the course. In this case, the Level 1 activities students engaged in (calculating, following procedure) supported the Level 3 activities (analyzing data, using concepts to solve) that were directly aligned with the Level 3 learning outcomes ("apply the concepts of concrete mix design in groups and determine the concrete constituent's proportions"). Furthermore, the instructor explicitly communicated these learning outcomes to students at the beginning of class, making the alignment and activity rationale clear to students, too. Since the classroom practice in this case study engaged students in active tasks, other observation protocols would likely identify this as an effective class meeting. In using the ELCOT, we also identify this class as effective, but the ELCOT allows us to push beyond a simple "active" label and identify specific ways in which the classroom was active.

Case Study 2 – Lecture-Driven Class Meeting

The second case study was an observation of an introductory calculus course, the second of a sequence of three, which was taught by a teaching associate professor who had participated in the first Engineering Learning Intensive. This calculus sequence is required of all undergraduate students at the university and, as such, enrolled a more diverse student body than the Case Study 1 course. In the semester of this observation, the course enrolled 42 students (40% women and 60% men), most of whom were freshmen (52%) or sophomores (43%), with a much smaller proportion of juniors (5%). Students in this course represented 11 different majors from across the university. The instructor noted that this observation occurred near the beginning of a unit, following a test in the previous class meeting, so students were just being introduced to the content. The learning outcomes for the class meeting were for students to: "Write an infinite series using sigma notation; find a sequence of partial sums and determine whether the sequence of partial sums converges or diverges; and find the sum of a convergent telescoping series." Thus, compared to the learning outcomes in Case Study 1, these reflect activities closer to Level 1, such as following procedure or calculating, or Level 2, such as generating and classifying data.

The pattern of classroom activity also looked very different from what was observed in Case Study 1 (see Table 1). Most notably, the instructor spent most of class time lecturing (92%) and demonstrating problem solving (92%), addressing students as a whole group (100%). Students did not spend any time working in groups, but the instructor did pose five individual tasks. During class, students spent the vast majority of time (88%) engaged in Level 1 activities, such as calculating, following procedure, and taking notes. However, compared to Case Study 1, both the instructor and students asked many more questions. The instructor primarily asked questions that required students to engage at Level 1 (15, 68% of all questions asked) and Level 2 (7, 32% of all questions asked), and students answered 14 (64%) of these questions. Students also asked the instructor 14 questions, the majority of which (10, 71%) were conceptual in nature, not simply administrative or clarifying, and she explicitly addressed 8 of these questions (57%).

Case Study 2 provides an interesting contrast to Case Study 1. If the class meeting in Case Study 2 had been observed using a different observation protocol, it likely would have been characterized as much less active than the class meeting in Case Study 1, and, by extension, assumed to be less effective than the more active class meeting. However, using the ELCOT protocol reveals a more nuanced picture and leads to a different conclusion. While it is true that students were engaged in lower level activities and did not work with peers during Case Study 2, ELCOT focuses attention on alignment first, before assessing instructor and student activity. In this case, the learning outcomes for the class session mapped to Level 1 and Level 2, as would be appropriate for the first time that students engaged with new content. Instructor and student activity during this class meeting also mapped to these lower levels, with students spending time practicing with the new content and the instructor asking and answering questions to assess students' progress. As such, these activities were properly aligned to the class's learning outcomes. Thus, although the patterns of activity in this class meeting may have been considered passive and thus a cause for concern if observed using a different protocol, when observed using ELCOT, these patterns instead reveal a well-aligned and effective class meeting.

Discussion

These two case studies illustrate the power of the Engineering Learning Classroom Observation Tool (ELCOT) to bring to light aspects of teaching and learning that other protocols miss but that are crucial for interpreting observation data. Without attending to the alignment between classroom activities and learning outcomes, classes that do not extensively use active learning but that are nonetheless well aligned may be mistakenly considered lacking, while classes that use strategies that are active but not appropriately aligned may be regarded as very effective. As our understanding of active learning becomes more nuanced, reflecting a clearer sense of the strategies that work for different populations of students in different contexts, it is important that our tools are also able to capture these nuances. For this reason, we argue that the ELCOT can serve an important role in helping the field of Engineering Education take "a more nuanced approach to active learning" (Streveler & Menekse, 2017, p. 189).

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Appendix A – ELCOT Qualitative Notes

Pre-Observation Notes

1. Which instructor are you observing? (Drop down)
2. What are the learning outcomes for the lesson? (Open-ended)
3. Is this lesson typical for the course? Y/N
4. What tasks or problems are planned for the students to work on? (Open-ended)
5. Anything else worth noting about the context? (Open-ended)

In-Class Notes

1. Were the learning outcomes communicated to students? Y/N
2. How many students were present at the beginning of class? (Open-ended)
3. Notes (Open-ended)

Post-Observation Notes

1. Did the task and talk align with the learning outcomes? Y/N
2. Were the learning outcomes assessed? Y/N
3. What proportion of students engaged in the task or activities? < 25%, 26-50%, 51-75%, 76-100%)
4. Notes on the overall class (Open-ended)

Appendix B – ELCOT Quantitative Codes

STUDENT CODES				INSTRUCTOR CODES	
Student Organization	**Nonproductive**	**L2 Organize**	**L4 Create**	**Noncontent**	**Interaction**
Individual	Waiting	Summarizing or recapping	Synthesizing	Not engaged with students	Building community or rapport
Small Group	Disrupting or off task	Classifying, comparing, organizing data/info	Critiquing	Administration	Monitoring work
Large Whole	**Passive**	Generating or collecting data/info	Making explicit connections	**Instructor Centered**	Interacting with small group
Student Talk	Listening passively	Developing or interpreting models/graphics	Designing	Lecturing	Interacting with one student
Answers Question*	**L1 Rote**	**L3 Apply**	Defending explanation	Using a visual aid	**Assessing and Advancing**
Asks Question*	Taking notes	Using concepts to solve	Reflection on own learning	Demonstrating problem solving	Asks question*
Discussion	Recalling info/procedures	Analyzing data		Modeling thinking	Providing wait time
Presentation	Calculating	Explaining using concepts or data			Answers question*
	Following procedure	Considering alternate interpretations			Poses task*
		Revising work	Other student activity	Other instructor activity	

*Codes with subcodes (see below)

<u>Student Codes</u>

Student Talk – Answers Question

- Provides an answer (closed)
- Explains/elaborates (open)

Student Talk – Asks Question

- Administrative Question
- Clarifying Question
- Conceptual Question

<u>Instructor Codes</u>

Assessing and Advancing – Asks Question

- Recall (L1)
- Summarize, compare, report out, key ideas (L2)
- Explain (L3)
- What if? Extending student thinking (L4)

Assessing and Advancing – Answers Question

- Answers Student Question
- Answers Own Question

Assessing and Advancing – Poses Task

- Individual Task
- Group Task

Appendix C – ELCOT Coding Manual

Category	Code Name	Description
STUDENT CODES		
Student Organization	Individual	Students are asked or choose to complete a task by themselves.
	Small Group	Students are asked or choose to work with a partner or group (2-5 students)
	Large Group	Students work in large groups (10 or more) or as a whole class (incl. individual note-taking during lecture)
Student Talk	Answers Question	Student answers a question posed by instructor or other student.
	- Noncontent/compliance reply (yes or no answer)	- Y/N response to management, other noncontent questions
	- Provides an answer (closed)	- Provides answer to instructor question; no explanation/elaboration
	- Explains/elaborates (open)	- More in depth than recall; explains process of arriving at answer
	- Other	- Catch-all for other questions; make a note in qualitative section!
	Asks Question	Student asks a question
	- Administrative	- about coursework, policies, logistics ("when is this due?" "Will this be on the test?")
	- Clarifying	- to check understanding of content ("could you explain that again?" "Why is it that...?")
	- Conceptual	- elaborates/extends content ("what would happen if?" "If we change that...?")
	- Other/Can't Tell/Off-Task	- Any other student question not captured by other codes
	Discussion	Students discuss; if instructor is facilitating, students are doing most of the talking
	Presentation	Students make a presentation to the whole class
	Student approaches instructor to talk	Student goes up to instructor to talk
Nonproductive	Waiting	Students waiting. No clear directions.
	Disrupting/off task	More than half the students are disruptive, off-task, or nonproductive.
Passive	Passively listening	Listening to instructor or other students passively
L1 Rote	Taking notes	Listening and taking notes during a lecture, presentation, demonstration or other activity
	Recalling info or procedures	Recalling a fact, information, or procedure; processing information at a low level
	Calculating	Straight computation; plug and chug
	Following procedure	Following procedure or steps mechanically (requires little thinking)
L2 Organize	Summarizing or recapping	Summarizing, reviewing

	Classifying organizing comparing data or info	Manipulating, organizing, describing, categorizing data or information
	Generating or collecting data or info	Collecting data and evidence; searching for info (online, text, other sources). Requires more thought than following cook-book style procedures and measurements
	Developing or interpreting models or graphics	Students develop or interpret models, graphs, diagrams, or other representations
L3 Apply Manipulate	Using concepts to solve	Students use concepts to solve problems, not just using formulae; moves beyond plug and chug computation
	Analyzing data	Students analyze data they generated or that was provided for them.
	Explaining using concepts or data	Drawing conclusions from data, using concepts to explain; not merely recall.
	Considering alternate interpretations	Students develop, compare and/or contrast alternate interpretations of data or information
	Revising work	Students work to revise earlier work based on feedback.
L4 Create Critique	Synthesizing	Students synthesize information from multiple sources.
	Critiquing	Students critique other works, peers, or outside sources and provide feedback.
	Making explicit connections	Students make explicit connections between an activity and the key concept or learning outcome.
	Designing	Students design an experiment, study, or solution
	Defending explanation	Students defend their explanation (claim-evidence-reasoning); respond to critique or questions from peers/instructor; compare/argue for their explanation relative to peers' or explanations in the literature
	Reflecting on own learning	Students reflect on what they have learned and or how they have learned
Other	Other student activity	Any other student activities not captured by other codes
INSTRUCTOR CODES		
Noncontent	Not engaged with students	Standing behind podium, looking at notes, organizing materials
	Administration	Discussing homework, due dates, reminders
Instructor Centered	Lecturing	Instructor holds the floor, describing/explaining
	Using a visual aid	Actively using the visual aid in teaching (not simply an image on a slide); video, illustration, diagram, or animation
	Demonstrating problem solving	Works through a problem or computation on the board or screen
	Modeling thinking	Describes how they would approach a problem, questions they would ask, factors they pay attention to
Interaction	Building community or rapport	Uses student names, uses humor, interacts with students around noncontent

	Monitoring work	Listening/paying attention to groups or individual students working on a task
	Interacting with small group	Helps, questions, answers group (including one student acting as spokesperson for the group); click each time the instructor interacts with a different group
	Interacting with one student	Helps, questions, answers one student (not acting as spokesperson for group); click each time the instructor interacts with a different student
Assessing or Advancing	Poses question	Poses question
	- Rhetorical/No response expected	- No student responses expected, rhetorical
	- Management	- Management question ("does everyone have a handout?", "did everyone hear?", "any questions?")
	- Recall (L1)	- Provide answer to instructor question; recall; no additional processing required
	- Summarize, compare, report out, key ideas (L2)	- Asks students to do low level processing of info; more than recall, less than explain
	- Explain (L3)	- More in depth than recall; explain/describe process of arriving at answer or reasoning
	- What if? Extending student thinking (L4)	- Pushes student to elaborate or consider alternatives
	- Other	- Catch-all for other questions; make a note in qualitative section!
	Providing wait time	Allows wait time after posing a question or task to open space for students to respond.
	Answers question	Answers question
	- Answers own question	- Answers own question
	- Answers student question	- Answers student question
	Poses task	Poses task
	- Individual task	- Asks students to work individually
	- Group task	- Asks students to work in groups
Other	Other instructor activity	Any other instructor activities not captured by other codes