Solutions Stats

Some questions raised by my plots for Q10, about solutions (solutions_plots.qmd):
- Are solution scores by job category the same for all possible pairs of job groups?
- Are non-research staff significantly more likely than other groups to want a learning community?
- Are aspiring contributors significantly more likely than experienced contributors to select solutions related to learning and professional development?
- Are experienced contributors significantly more likely than aspiring contributors to select solutions related to funding?

Set seed

```
set.seed(42)
```

Import packages and utilities

```
project_root <- here::here() # requires that you be somewhere in the
# project directory (not above it)
# packages
suppressMessages(source(file.path(project_root, "scripts/packages.R")))
# functions and objects used across scripts
suppressMessages(source(file.path(project_root, "scripts/utils.R")))
```

Load data

```
solutions <- load_qualtrics_data("clean_data/solutions_Q10.tsv")
other_quant <- load_qualtrics_data("clean_data/other_quant.tsv")
```

Wrangle data

First, let's add a participant ID. We'll need to keep track of these track these since observations from the same participant are not independent. We'll need to model the participants as a random effect.

```
solutions$participantID <- seq(1, nrow(solutions))
```

Next, remove empty rows, i.e. rows from respondents who didn't receive this question. As with many questions in this survey, we can cut some corners in the code because the question was mandatory. For example, no need to worry about incomplete answers.

```
solutions_and_job <- solutions
solutions_and_job$job_category <- other_quant$job_category
names(solutions_and_job)[length(names(solutions_and_job))] <- "job_category"

nrow(solutions_and_job)
```

```
[1] 332
```

```
# from scripts/utils.R
solutions_and_job <- exclude_empty_rows(solutions_and_job, strict=TRUE)
nrow(solutions_and_job)
```

```
[1] 233
```

Good. We know by now that only 233 participants saw this question.

Here's what we have so far:

```
head(solutions_and_job)
```

```
  Computing environments        Publicity Containerization Documentation help
1            Very useful      Very useful      Very useful         Very useful
2                 Useful      Very useful      Very useful    Not very useful
3            Very useful      Very useful      Very useful         Very useful
4        Not very useful           Useful           Useful         Very useful
5                 Useful  Not very useful           Useful         Very useful
7        Not very useful  Not very useful      Very useful    Not very useful
  A learning community  Event planning Mentoring programs        Education
1           Very useful     Very useful        Very useful      Very useful
2                Useful   Non-applicable        Very useful      Very useful
3                Useful          Useful             Useful  Not very useful
4       Not very useful          Useful    Not very useful  Not very useful
5       Not very useful Not very useful             Useful      Very useful
7       Not very useful Not very useful    Not very useful  Not very useful
  Legal support Industry partnerships Sustainability grants
1   Very useful           Very useful           Very useful
2   Very useful                Useful           Very useful
3   Very useful           Very useful           Very useful
4        Useful       Not very useful           Very useful
5        Useful                Useful           Very useful
7   Very useful       Not very useful           Very useful
  Help finding funding participantID        job_category
1          Very useful             1             Faculty
2               Useful             2            Post-Doc
3          Very useful             3 Other research staff
4          Very useful             4             Faculty
5               Useful             5             Faculty
7          Very useful             7             Faculty
```

Convert to long data, since this makes it easier to remove NAs and is necessary for the statistics.

```r
long_data <- solutions_and_job %>%
  pivot_longer(
    cols = -c(participantID, job_category),
    names_to = "solution",
    values_to = "utility"
  )
dim(long_data)
```

```
[1] 2796    4
```

```r
head(long_data)
```

```
# A tibble: 6 x 4
  participantID job_category solution              utility
          <int> <chr>        <chr>                 <chr>
1             1 Faculty      Computing environments Very useful
2             1 Faculty      Publicity             Very useful
3             1 Faculty      Containerization      Very useful
4             1 Faculty      Documentation help    Very useful
5             1 Faculty      A learning community  Very useful
6             1 Faculty      Event planning        Very useful
```

Remove NAs.

```r
long_data <- long_data %>%
    filter(!(utility == "Non-applicable"))
dim(long_data)
```

```
[1] 2602    4
```

That removed about 200 rows, out of more than 2000. So less than 10% of the responses were "non-applicable"s.

Make utility an ordered factor. Solution and job category are not inherently ordered, but we'll make them factors, and the first factor level will be the reference level for that variable. It doesn't really matter which level we use as the reference level.

```r
long_data$utility <- factor(
  long_data$utility,
  levels = c("Not very useful", "Useful", "Very useful"),
  ordered = TRUE
)

long_data$solution <- factor(
  long_data$solution,
  levels = unique(long_data$solution)
)

long_data$job_category <- factor(
  long_data$job_category,
```

```
  levels = unique(long_data$job_category)
)

levels(long_data$solution)
```

```
 [1] "Computing environments" "Publicity"             "Containerization"
 [4] "Documentation help"     "A learning community"  "Event planning"
 [7] "Mentoring programs"     "Education"             "Legal support"
[10] "Industry partnerships"  "Sustainability grants" "Help finding funding"
```

```
levels(long_data$job_category)
```

```
[1] "Faculty"             "Post-Doc"            "Other research staff"
[4] "Grad Student"        "Non-research Staff"  "Undergraduate"
```

Ok, so it looks like our reference levels are computing environments and faculty. That's fine. It doesn't really matter.

Create candidate models

I'd like to fit a cumulative-logit mixed model, a.k.a. an ordinal regression model, using the clmm function from the ordinal package. (I am not using polr from the MASS package because it does not allow random effects.) I know we want to include participantID as a random effect, but I'm not really sure how to model solution. I think it would be best to compare different models.

Note that the next few cells take several minutes to run.

Model 1: job_category * solution interaction

Here, I'm modeling job_category and solution as independent fixed effects, and assuming that there is also an effect from the interaction of the two. This way, we get a global slope for job_category, a global slope for solution, a global slope for the interaction (I think), and a global intercept. Adding participant as a random effect allows each participant to have their own deviation from the global intercept.

```
fit1 <- ordinal::clmm(utility ~ job_category * solution +
              (1 | participantID),
           data = long_data, link = "logit", Hess = TRUE)
```

```
Warning: (1) Hessian is numerically singular: parameters are not uniquely determined
In addition: Absolute convergence criterion was met, but relative criterion was not met
```

Hm. I get a warning that "Hessian is numerically singular: parameters are not uniquely determined" and "Absolute convergence criterion was met, but relative criterion was not met". The internet suggests that this might mean that some job-category $\times$ solution combinations have few or zero responses in one of the utility levels, so the full job_category * solution interaction is over-parameterised.

Model 2: solution as a random effect, no correlation between participant intercept and job effect

Here's another formulation. In this case, solution is another random effect, so we only get one global slope from job_category, but each solution intercept (as well as each participant intercept) is allowed to deviate from the global intercept. We assume that across solutions, the deviations in job_cateogry effect from the global effect of job_category are not correlated with that solution's intercept's deviation from the global intercept.

```
fit2 <- ordinal::clmm(utility ~ job_category +
               (1 | solution) +
               (1 | participantID) +
               (0 + job_category | solution),
            data = long_data, link = "logit", Hess = TRUE)
```

Next, we again have 4 terms, like we did in the first model: a global intercept, slopes for job_category and solution, and a slope for the interaction. Now, we also estimate the deviance of each of these terms from the global baseline for each participant, and we also estimate the correlations between the deviations for each possible combination of the 4 terms, for each participant. Er, I think. (Helpful cheat sheet: https://stats.stackexchange.com/questions/13166/rs-lmer-cheat-sheet)

This one measures a ton of parameters... ABANDONED; NEVER CONVERGED

```
# fit3 <- ordinal::clmm(utility ~ job_category * solution +        # fixed effects
#                 (0 + job_category*solution | participantID),
#             data = long_data, link = "logit", Hess = TRUE)
```

All the models seem to be struggling a bit. Let's explore the data for a moment.

```
# three way cross tabs (xtabs) and flatten the table
# code from: https://ladal.edu.au/tutorials/regression/regression.html
ftable(xtabs(~ job_category + solution + utility, data = long_data))
```

job_category	solution	utility Not very useful	Useful	Very useful
Faculty	Computing environments	12	17	29
	Publicity	19	12	24
	Containerization	19	17	18
	Documentation help	21	18	17
	A learning community	21	26	10
	Event planning	24	19	11
	Mentoring programs	24	23	8
	Education	24	21	12
	Legal support	15	28	12
	Industry partnerships	18	15	23
	Sustainability grants	3	10	44
	Help finding funding	5	13	36
Post-Doc	Computing environments	4	3	8
	Publicity	2	6	7
	Containerization	5	4	6
	Documentation help	4	6	5
	A learning community	2	9	4
	Event planning	5	3	6
	Mentoring programs	3	7	5
	Education	2	6	7
	Legal support	2	5	7
	Industry partnerships	4	3	7
	Sustainability grants	0	3	12
	Help finding funding	0	6	9
Other research staff	Computing environments	10	11	19
	Publicity	6	15	16
	Containerization	14	17	8
	Documentation help	8	14	16
	A learning community	8	19	11
	Event planning	13	14	11
	Mentoring programs	12	13	10
	Education	11	15	11
	Legal support	14	11	13
	Industry partnerships	9	12	14
	Sustainability grants	3	7	28
	Help finding funding	2	11	23
Grad Student	Computing environments	1	6	19
	Publicity	2	10	11
	Containerization	3	10	9
	Documentation help	5	8	13
	A learning community	5	9	12

	Event planning	7	6	11
	Mentoring programs	4	10	12
	Education	5	7	14
	Legal support	3	10	12
	Industry partnerships	3	11	12
	Sustainability grants	0	1	25
	Help finding funding	0	5	20
Non-research Staff	Computing environments	13	32	35
	Publicity	26	33	15
	Containerization	33	24	20
	Documentation help	19	39	26
	A learning community	11	43	31
	Event planning	29	30	16
	Mentoring programs	18	35	24
	Education	21	31	30
	Legal support	13	41	26
	Industry partnerships	23	29	18
	Sustainability grants	8	25	39
	Help finding funding	9	31	32
Undergraduate	Computing environments	0	2	5
	Publicity	0	2	4
	Containerization	1	1	4
	Documentation help	1	3	3
	A learning community	2	1	4
	Event planning	2	2	3
	Mentoring programs	0	4	3
	Education	1	4	2
	Legal support	1	3	2
	Industry partnerships	0	0	7
	Sustainability grants	0	1	5
	Help finding funding	0	2	4

Hm. Indeed, the data are sparse in places, particularly for undergraduates. Perhaps we should combine postdocs + staff researchers, as well as undergrads + grad students.

```
combined <- long_data %>%
  mutate(
    job_category = recode(
      job_category,
      "Post-Doc" = "Postdocs and Staff Researchers",
      "Other research staff" = "Postdocs and Staff Researchers"
    )
```

```
  )

combined <- combined %>%
  mutate(
    job_category = recode(
      job_category,
      "Grad Student" = "Students",
      "Undergraduate" = "Students"
    )
  )
```

Now let's run models 1 and 2 again, but with this consolidated dataset.

Model 1b: Model 1, but with consolidated data

```
fit1b <- ordinal::clmm(utility ~ job_category * solution +
            (1 | participantID),
          data = combined, link = "logit", Hess = TRUE)
```

No warning this time, and I feel like it finished faster. My hunch is that this re-labeled dataset will lead to better results.

Model 2b: Model 2, but with consolidated data

```
fit2b <- ordinal::clmm(utility ~ job_category +
            (1 | solution) +
            (1 | participantID) +
            (0 + job_category | solution),
          data = combined, link = "logit", Hess = TRUE)
```

So, those are two fairly complex models that I think capture the important variation. Let's compare them to some simpler models.

Model 3: No job category

Let's make a null model where job category doesn't matter. (Using the consolidated data)

```
fit3 <- ordinal::clmm(utility ~ solution +
              (1 | participantID),
           data = combined, link = "logit", Hess = TRUE)
```

Model 4: No solution category

How about a model where solution doesn't matter?

```
fit4 <- ordinal::clmm(utility ~ job_category +
              (1 | participantID),
           data = combined, link = "logit", Hess = TRUE)
```

Model 5: job_category + solution

In this minimal model, we include job_category + solution, but without any interaction. This model says that we can predict the rating by simply adding the effect of job category and the effect of solution, with no additional effect from combining a particular job category with a particular solution.

```
fit5 <- ordinal::clmm(utility ~ job_category + solution +
              (1 | participantID),
           data = combined, link = "logit", Hess = TRUE)
```

Model 6: no random effects

Do we really need to account for participants' individual baselines?

```
# note clm function bc clmm is for mixed models
fit6 <- ordinal::clm(utility ~ job_category * solution,
           data = combined, link = "logit", Hess = TRUE)
```

Compare models

```
models <- list(
  "fit1"=fit1, # job_category * solution, sparser data
  "fit2"=fit2, # solution as random effect, sparser data
  "fit1b"=fit1b, # job_category * solution, denser data
  "fit2b"=fit2b, # solution as random effect, denser data
  "fit3"=fit3, # Null model: no job
  "fit4"=fit4, # Null model: no solution
  "fit5"=fit5, # Null model: no interaction
  "fit6"=fit6 # Null model: no participants
)
```

First, let's get a general sense of goodness-of-fit by looking at the AICs. You're not supposed to compare AICs for models fit to different data sets (models 1 and 2 are using the sparser data), but since I've only changed the job_category labels, but not the observations or the number of observations, I think this is ok.

```
sapply(models, function(x) round(stats::AIC(x)))
```

```
 fit1  fit2 fit1b fit2b  fit3  fit4  fit5  fit6
 4826  4847  4802  4827  4836  5094  4822  5348
```

The AICs for all the models are fairly similar, except in two cases: #4, where solution isn't doesn't matter, and job_category alone influences the response, and #6, where participant ID doesn't matter. Both of these make sense. Model 5, where job category and solution have no interaction, does fairly well. Maybe job-solution interactions are subtle.

Model 1b looks the best. According to the internet, a delta AIC of more than ten is pretty substantial, and here we have a difference of 20 between the best and second-best.

Let's check the condition number of the Hessian. I don't really understand what this is, but the clmm2 tutorial says that high numbers, say larger than say 10^4 or 10^6, indicate poor fit.

```
sapply(models, function(x)
summary(x)$info["cond.H"]
)
```

```
Warning in summary.clmm(x): Variance-covariance matrix of the parameters is not
defined
```

```
$fit1.cond.H
[1] "NaN"

$fit2.cond.H
[1] "3.9e+02"

$fit1b.cond.H
[1] "2.8e+03"

$fit2b.cond.H
[1] "2.1e+02"

$fit3.cond.H
[1] "1.5e+02"

$fit4.cond.H
[1] "1.2e+02"

$fit5.cond.H
[1] "1.6e+02"

$fit6.cond.H
[1] "3.9e+03"
```

Okay, depending on my random seed, fit1 either gives a NaN or a high value here. All the other models look decent.

Complex models vs null models

Let's use an anova to compare the two models that scored the best in terms of AIC. Since they also happen to be nested, an anova works here.

```
stats::anova(fit1b, fit5)
```

```
Likelihood ratio tests of cumulative link models:

      formula:                                                  link: threshold:
fit5  utility ~ job_category + solution + (1 | participantID) logit flexible
fit1b utility ~ job_category * solution + (1 | participantID) logit flexible

      no.par   AIC  logLik LR.stat df Pr(>Chisq)
```

```
fit5      17 4822.2 -2394.1
fit1b     50 4802.0 -2351.0  86.199 33  1.221e-06 ***
---
Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
```

That's a significant p-value. It looks like the interaction term is worth including.

Let's also double-check that participants are worth including.

```
stats::anova(fit1b, fit6)
```

```
Likelihood ratio tests of cumulative link models:

      formula:                                                link: threshold:
fit6  utility ~ job_category * solution                       logit flexible
fit1b utility ~ job_category * solution + (1 | participantID) logit flexible

      no.par    AIC  logLik LR.stat df Pr(>Chisq)
fit6      49 5348.3 -2625.2
fit1b     50 4802.0 -2351.0  548.36  1  < 2.2e-16 ***
---
Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
```

Yep, definitely want to include those.

Does it matter whether we include job as a variable? Let's compare it to the model with job + solution, without an interaction term.

```
stats::anova(fit3, fit5)
```

```
Likelihood ratio tests of cumulative link models:

      formula:                                             link: threshold:
fit3 utility ~ solution + (1 | participantID)              logit flexible
fit5 utility ~ job_category + solution + (1 | participantID) logit flexible

      no.par    AIC  logLik LR.stat df Pr(>Chisq)
fit3      14 4836.1 -2404.0
fit5      17 4822.2 -2394.1  19.902  3  0.0001779 ***
---
Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
```

It appears that job is also significant in explaining the variation in the data.

More goodness of fit evaluation

How else to evaluate the models? The `ordinal` package provides goodness-of-fit functions nominal_test and scale_test, but as far as I can tell, these only work on clm objects, not clmm objects. (mixed models)

Model 2b had a similar AIC as model 5. While I can't compare model 1b and model 2b with anova, since they're not nested, I can at least glance at the standard errors of the coefficients, which give me a sense of the precision of the coefficient estimates.

```
summary(fit1b$coefficients)
```

```
    Min.  1st Qu.   Median     Mean  3rd Qu.     Max.
-2.15349 -0.68400 -0.05181 -0.07111  0.77637  1.73451
```

```
summary(fit2b$coefficients)
```

```
    Min.  1st Qu.   Median     Mean  3rd Qu.     Max.
-1.38345  0.06018  0.50278  0.30830  0.91531  1.44669
```

Hm. So fit1b had the lowest AIC of all the models and is significantly better at explaining the variation than the equivalent minimal model without an interaction term. However, the coefficients of fit2b have smaller SEs than those of fit1b.

How about the log likelihoods?

```
LL <- sapply(models, function(x) x$logLik)
# These are a bit hard to read to I am reordering them
LL[order(LL)]
```

```
     fit6      fit4      fit3     fit2b      fit5      fit2     fit1b      fit1
-2625.165 -2541.072 -2404.033 -2396.590 -2394.082 -2393.642 -2350.983 -2339.214
```

In this case, surprisingly, fit1 looks best. But only #4 and #6 look really bad. The rest are sort of close together, and fit1b is second best, not too far behind fit1.

So, I find myself in the annoying situation of having several g-o-f tests that don't quite agree. However, I think I'll go with fit1b. It had the best AIC and the second-best log-likelihood. The SEs are a little concerning, but I don't think the SEs are a super reliable indicator of g-o-f anyway. This model consistently had pretty good g-o-f metrics, and I think it also intuitively makes the most sense.

Interpreting the model results

```
summary(fit1b)
```

```
Cumulative Link Mixed Model fitted with the Laplace approximation

formula: utility ~ job_category * solution + (1 | participantID)
data:    combined

 link  threshold nobs logLik   AIC     niter        max.grad cond.H
 logit flexible  2602 -2350.98 4801.97 10197(40741) 1.22e-03 2.8e+03

Random effects:
 Groups        Name        Variance Std.Dev.
 participantID (Intercept) 2.097    1.448
Number of groups:  participantID 232

Coefficients:
```

	Estimate
job_categoryPostdocs and Staff Researchers	-0.04736
job_categoryStudents	1.66906
job_categoryNon-research Staff	-0.08350
solutionPublicity	-0.66811
solutionContainerization	-1.06243
solutionDocumentation help	-1.21045
solutionA learning community	-1.56910
solutionEvent planning	-1.83275
solutionMentoring programs	-1.93070
solutionEducation	-1.68608
solutionLegal support	-1.18188
solutionIndustry partnerships	-0.68400
solutionSustainability grants	1.73451
solutionHelp finding funding	1.08082
job_categoryPostdocs and Staff Researchers:solutionPublicity	0.78228
job_categoryStudents:solutionPublicity	-0.49909
job_categoryNon-research Staff:solutionPublicity	-0.74669
job_categoryPostdocs and Staff Researchers:solutionContainerization	-0.03388
job_categoryStudents:solutionContainerization	-0.64866
job_categoryNon-research Staff:solutionContainerization	-0.42332
job_categoryPostdocs and Staff Researchers:solutionDocumentation help	0.94435
job_categoryStudents:solutionDocumentation help	-0.35912

```
job_categoryNon-research Staff:solutionDocumentation help                      0.53196
job_categoryPostdocs and Staff Researchers:solutionA learning community        1.02260
job_categoryStudents:solutionA learning community                             -0.10889
job_categoryNon-research Staff:solutionA learning community                    1.44068
job_categoryPostdocs and Staff Researchers:solutionEvent planning              0.91886
job_categoryStudents:solutionEvent planning                                   -0.22759
job_categoryNon-research Staff:solutionEvent planning                          0.35351
job_categoryPostdocs and Staff Researchers:solutionMentoring programs          1.04164
job_categoryStudents:solutionMentoring programs                                0.45731
job_categoryNon-research Staff:solutionMentoring programs                      1.24157
job_categoryPostdocs and Staff Researchers:solutionEducation                   1.16078
job_categoryStudents:solutionEducation                                         0.19222
job_categoryNon-research Staff:solutionEducation                               1.12431
job_categoryPostdocs and Staff Researchers:solutionLegal support              0.54219
job_categoryStudents:solutionLegal support                                    -0.35340
job_categoryNon-research Staff:solutionLegal support                          0.77637
job_categoryPostdocs and Staff Researchers:solutionIndustry partnerships       0.34019
job_categoryStudents:solutionIndustry partnerships                            -0.23308
job_categoryNon-research Staff:solutionIndustry partnerships                  -0.46161
job_categoryPostdocs and Staff Researchers:solutionSustainability grants      -0.05181
job_categoryStudents:solutionSustainability grants                            0.28703
job_categoryNon-research Staff:solutionSustainability grants                  -1.21278
job_categoryPostdocs and Staff Researchers:solutionHelp finding funding       -0.02601
job_categoryStudents:solutionHelp finding funding                             -0.76619
job_categoryNon-research Staff:solutionHelp finding funding                   -1.03639
                                                                              Std. Error
job_categoryPostdocs and Staff Researchers                                     0.49392
job_categoryStudents                                                          0.61824
job_categoryNon-research Staff                                                0.44158
solutionPublicity                                                             0.40568
solutionContainerization                                                      0.40387
solutionDocumentation help                                                    0.39881
solutionA learning community                                                  0.38854
solutionEvent planning                                                        0.40245
solutionMentoring programs                                                    0.39813
solutionEducation                                                             0.39749
solutionLegal support                                                         0.39142
solutionIndustry partnerships                                                 0.40142
solutionSustainability grants                                                 0.44904
solutionHelp finding funding                                                  0.42632
job_categoryPostdocs and Staff Researchers:solutionPublicity                   0.57881
job_categoryStudents:solutionPublicity                                        0.72018
job_categoryNon-research Staff:solutionPublicity                              0.52227
```

```
job_categoryPostdocs and Staff Researchers:solutionContainerization    0.57095
job_categoryStudents:solutionContainerization                          0.71859
job_categoryNon-research Staff:solutionContainerization                0.52130
job_categoryPostdocs and Staff Researchers:solutionDocumentation help  0.57355
job_categoryStudents:solutionDocumentation help                        0.70165
job_categoryNon-research Staff:solutionDocumentation help              0.50803
job_categoryPostdocs and Staff Researchers:solutionA learning community 0.55805
job_categoryStudents:solutionA learning community                      0.69278
job_categoryNon-research Staff:solutionA learning community            0.49959
job_categoryPostdocs and Staff Researchers:solutionEvent planning      0.57443
job_categoryStudents:solutionEvent planning                            0.71107
job_categoryNon-research Staff:solutionEvent planning                  0.51964
job_categoryPostdocs and Staff Researchers:solutionMentoring programs  0.57321
job_categoryStudents:solutionMentoring programs                        0.69274
job_categoryNon-research Staff:solutionMentoring programs              0.51079
job_categoryPostdocs and Staff Researchers:solutionEducation           0.57092
job_categoryStudents:solutionEducation                                 0.69830
job_categoryNon-research Staff:solutionEducation                       0.51032
job_categoryPostdocs and Staff Researchers:solutionLegal support       0.56944
job_categoryStudents:solutionLegal support                             0.69631
job_categoryNon-research Staff:solutionLegal support                   0.50550
job_categoryPostdocs and Staff Researchers:solutionIndustry partnerships 0.58203
job_categoryStudents:solutionIndustry partnerships                     0.71261
job_categoryNon-research Staff:solutionIndustry partnerships           0.52272
job_categoryPostdocs and Staff Researchers:solutionSustainability grants 0.63964
job_categoryStudents:solutionSustainability grants                     0.99068
job_categoryNon-research Staff:solutionSustainability grants           0.56400
job_categoryPostdocs and Staff Researchers:solutionHelp finding funding 0.60587
job_categoryStudents:solutionHelp finding funding                      0.77727
job_categoryNon-research Staff:solutionHelp finding funding            0.54190
                                                                       z value
job_categoryPostdocs and Staff Researchers                             -0.096
job_categoryStudents                                                    2.700
job_categoryNon-research Staff                                         -0.189
solutionPublicity                                                      -1.647
solutionContainerization                                              -2.631
solutionDocumentation help                                            -3.035
solutionA learning community                                         -4.038
solutionEvent planning                                               -4.554
solutionMentoring programs                                           -4.849
solutionEducation                                                    -4.242
solutionLegal support                                                -3.019
solutionIndustry partnerships                                        -1.704
```

```
solutionSustainability grants                                                 3.863
solutionHelp finding funding                                                  2.535
job_categoryPostdocs and Staff Researchers:solutionPublicity                  1.352
job_categoryStudents:solutionPublicity                                       -0.693
job_categoryNon-research Staff:solutionPublicity                             -1.430
job_categoryPostdocs and Staff Researchers:solutionContainerization         -0.059
job_categoryStudents:solutionContainerization                               -0.903
job_categoryNon-research Staff:solutionContainerization                     -0.812
job_categoryPostdocs and Staff Researchers:solutionDocumentation help        1.646
job_categoryStudents:solutionDocumentation help                             -0.512
job_categoryNon-research Staff:solutionDocumentation help                    1.047
job_categoryPostdocs and Staff Researchers:solutionA learning community      1.832
job_categoryStudents:solutionA learning community                           -0.157
job_categoryNon-research Staff:solutionA learning community                  2.884
job_categoryPostdocs and Staff Researchers:solutionEvent planning            1.600
job_categoryStudents:solutionEvent planning                                 -0.320
job_categoryNon-research Staff:solutionEvent planning                        0.680
job_categoryPostdocs and Staff Researchers:solutionMentoring programs        1.817
job_categoryStudents:solutionMentoring programs                              0.660
job_categoryNon-research Staff:solutionMentoring programs                    2.431
job_categoryPostdocs and Staff Researchers:solutionEducation                 2.033
job_categoryStudents:solutionEducation                                       0.275
job_categoryNon-research Staff:solutionEducation                             2.203
job_categoryPostdocs and Staff Researchers:solutionLegal support             0.952
job_categoryStudents:solutionLegal support                                  -0.508
job_categoryNon-research Staff:solutionLegal support                         1.536
job_categoryPostdocs and Staff Researchers:solutionIndustry partnerships     0.584
job_categoryStudents:solutionIndustry partnerships                          -0.327
job_categoryNon-research Staff:solutionIndustry partnerships                -0.883
job_categoryPostdocs and Staff Researchers:solutionSustainability grants    -0.081
job_categoryStudents:solutionSustainability grants                           0.290
job_categoryNon-research Staff:solutionSustainability grants                -2.150
job_categoryPostdocs and Staff Researchers:solutionHelp finding funding     -0.043
job_categoryStudents:solutionHelp finding funding                           -0.986
job_categoryNon-research Staff:solutionHelp finding funding                 -1.912
                                                                         Pr(>|z|)
job_categoryPostdocs and Staff Researchers                               0.923611
job_categoryStudents                                                     0.006941
job_categoryNon-research Staff                                           0.850023
solutionPublicity                                                        0.099586
solutionContainerization                                                 0.008524
solutionDocumentation help                                               0.002404
solutionA learning community                                             5.38e-05
```

```
solutionEvent planning                                                       5.26e-06
solutionMentoring programs                                                   1.24e-06
solutionEducation                                                            2.22e-05
solutionLegal support                                                        0.002532
solutionIndustry partnerships                                                0.088390
solutionSustainability grants                                                0.000112
solutionHelp finding funding                                                 0.011237
job_categoryPostdocs and Staff Researchers:solutionPublicity                 0.176523
job_categoryStudents:solutionPublicity                                       0.488306
job_categoryNon-research Staff:solutionPublicity                             0.152797
job_categoryPostdocs and Staff Researchers:solutionContainerization          0.952681
job_categoryStudents:solutionContainerization                                0.366692
job_categoryNon-research Staff:solutionContainerization                      0.416773
job_categoryPostdocs and Staff Researchers:solutionDocumentation help        0.099662
job_categoryStudents:solutionDocumentation help                              0.608771
job_categoryNon-research Staff:solutionDocumentation help                    0.295052
job_categoryPostdocs and Staff Researchers:solutionA learning community      0.066882
job_categoryStudents:solutionA learning community                            0.875099
job_categoryNon-research Staff:solutionA learning community                  0.003930
job_categoryPostdocs and Staff Researchers:solutionEvent planning            0.109686
job_categoryStudents:solutionEvent planning                                  0.748914
job_categoryNon-research Staff:solutionEvent planning                        0.496319
job_categoryPostdocs and Staff Researchers:solutionMentoring programs        0.069187
job_categoryStudents:solutionMentoring programs                              0.509161
job_categoryNon-research Staff:solutionMentoring programs                    0.015071
job_categoryPostdocs and Staff Researchers:solutionEducation                 0.042035
job_categoryStudents:solutionEducation                                       0.783112
job_categoryNon-research Staff:solutionEducation                             0.027585
job_categoryPostdocs and Staff Researchers:solutionLegal support             0.341017
job_categoryStudents:solutionLegal support                                   0.611776
job_categoryNon-research Staff:solutionLegal support                         0.124579
job_categoryPostdocs and Staff Researchers:solutionIndustry partnerships     0.558895
job_categoryStudents:solutionIndustry partnerships                           0.743610
job_categoryNon-research Staff:solutionIndustry partnerships                 0.377183
job_categoryPostdocs and Staff Researchers:solutionSustainability grants     0.935446
job_categoryStudents:solutionSustainability grants                           0.772020
job_categoryNon-research Staff:solutionSustainability grants                 0.031531
job_categoryPostdocs and Staff Researchers:solutionHelp finding funding      0.965754
job_categoryStudents:solutionHelp finding funding                            0.324256
job_categoryNon-research Staff:solutionHelp finding funding                  0.055813

job_categoryPostdocs and Staff Researchers
job_categoryStudents                                                         **
```

```
job_categoryNon-research Staff
solutionPublicity                                                                .
solutionContainerization                                                         **
solutionDocumentation help                                                       **
solutionA learning community                                                     ***
solutionEvent planning                                                           ***
solutionMentoring programs                                                       ***
solutionEducation                                                                ***
solutionLegal support                                                            **
solutionIndustry partnerships                                                    .
solutionSustainability grants                                                    ***
solutionHelp finding funding                                                     *
job_categoryPostdocs and Staff Researchers:solutionPublicity
job_categoryStudents:solutionPublicity
job_categoryNon-research Staff:solutionPublicity
job_categoryPostdocs and Staff Researchers:solutionContainerization
job_categoryStudents:solutionContainerization
job_categoryNon-research Staff:solutionContainerization
job_categoryPostdocs and Staff Researchers:solutionDocumentation help    .
job_categoryStudents:solutionDocumentation help
job_categoryNon-research Staff:solutionDocumentation help
job_categoryPostdocs and Staff Researchers:solutionA learning community  .
job_categoryStudents:solutionA learning community
job_categoryNon-research Staff:solutionA learning community              **
job_categoryPostdocs and Staff Researchers:solutionEvent planning
job_categoryStudents:solutionEvent planning
job_categoryNon-research Staff:solutionEvent planning
job_categoryPostdocs and Staff Researchers:solutionMentoring programs     .
job_categoryStudents:solutionMentoring programs
job_categoryNon-research Staff:solutionMentoring programs                 *
job_categoryPostdocs and Staff Researchers:solutionEducation              *
job_categoryStudents:solutionEducation
job_categoryNon-research Staff:solutionEducation                          *
job_categoryPostdocs and Staff Researchers:solutionLegal support
job_categoryStudents:solutionLegal support
job_categoryNon-research Staff:solutionLegal support
job_categoryPostdocs and Staff Researchers:solutionIndustry partnerships
job_categoryStudents:solutionIndustry partnerships
job_categoryNon-research Staff:solutionIndustry partnerships
job_categoryPostdocs and Staff Researchers:solutionSustainability grants
job_categoryStudents:solutionSustainability grants
job_categoryNon-research Staff:solutionSustainability grants             *
job_categoryPostdocs and Staff Researchers:solutionHelp finding funding
```

```
job_categoryStudents:solutionHelp finding funding
job_categoryNon-research Staff:solutionHelp finding funding            .
---
Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

Threshold coefficients:
                      Estimate Std. Error z value
Not very useful|Useful  -2.1535     0.3461  -6.223
Useful|Very useful        0.1717     0.3425   0.501
```

This is a lot to interpret. I'll do my best. First, let's just at the main effects, i.e. the effects of job category and solution. In the summary above, each job category is compared to Faculty, our job reference level, for the solution Computing environments, our solution reference level. The "Estimate" for job_categoryStudents is 1.66906, which indicates students have odds of e^1.67=5.3 of rating that solution at least one category higher than faculty.

The solution Publicity has a coefficient of -0.66811, indicating that faculty have odds of e^0.67=2 of rating Publicity one level lower than Computing Environments.

The interactions, e.g. job_categoryPostdocs and Staff Researchers:solutionPublicity, indicate extra log-odds only for that specific job × solution pair beyond the two main effects. So in that example, postdocs and staff researchers have an extra log-odds of 0.78228 (odds of e^0.78228=2.186) of giving publicity a higher rating than computing environments, as compared to faculty.

Interestingly, none of our p-values are super significant for interactions, meaning none of the interactions are really significant on their own. The most significant effects (three asterisks) were all solutions: A learning community (-), Event planning (-), Mentoring programs (-), Education (-), Sustainability grants (+).

So, faculty had significantly higher odds of selecting sustainability grants than computing environments; significantly lower odds of selections education, mentoring, etc. than computing environments.

One job category did get two asterisks:
Coefficients:
Estimate Std. Error z value Pr($>$|z|)
job_categoryStudents 1.66906 0.61824 2.700 0.006941 **

So, students had somewhat significantly higher odds of selecting computing environments than faculty.

So, painting this with a really broad brush, we might say that responses vary across solutions more than they vary across job categories, at least in the sense that there are more significant differences within faculty than between faculty vs. students.

Since coefficients are hard to interpret, let's get contrasts using the emmeans package. The contrast essentially indicates the difference between two factors' effect sizes. So instead of comparing the coefficients by eye, we can just calculate contrasts that tell us how big the difference is, for each pair of coefficients.

Estimated marginal means

So, here's my attempt to make sense of a complicated post-hoc exploration of a complicated model. Ordinal regression with the `ordinal` package–and ordinal regression in general, I think–assumes that there is a continuous random variable–a "latent" variable–underlying the categorical outcomes. The category boundaries are then thresholds on the continuous function. The emmeans package gets estimated marginal means from your model: mean outcomes for certain variables while holding other variables constant. The emmeans function can be run in various modes that will change the reported means from the default "latent" scale (whose bounds are arbitrary) to something else. mode = "prob" will report descriptive statistics on the probability distribution of each rating. mode = "mean.class" will report the means of these distributions as probabilities on a scale of 1 to n, where n is the number of outcome categories in your data set. So if you have three outcomes, e.g. not very useful, useful, very useful, and you obtain an average rating of 2.1 for a particular solution with mode="mean.class", this means that the (estimated) average rating for that solution was 2.1, or, a teensy bit above "useful".

I'm using mode="mean.class" because I find it much easier to interpret an average rating (the sum of the probabilities of each of the three rating categories) than values on the arbitrary latent scale.

N.B.: A warning to keep in mind when using mode="prob", and I assume it also applies to mode="mean.class": https://stats.stackexchange.com/questions/615711/why-are-emmip-response-y-axis-numbers-not-probabilities-for-ordinal-regressi#:~:text=There%20are%20several%20ways%20to, I think we will be okay as long as we include job in the estimate formula?

emmeans also gives you the option to weight the means by averaging over a factor. This handy command lets us see the weights in our model. https://stats.stackexchange.com/questions/610912/emmeans-weights-for-unbalanced-groups-factors

```
ref_grid(fit1b)@grid
```

```
                    job_category                  solution .wgt.
1                        Faculty Computing environments    58
2  Postdocs and Staff Researchers Computing environments    55
3                       Students Computing environments    33
4             Non-research Staff Computing environments    80
```

```
5                        Faculty             Publicity  55
6  Postdocs and Staff Researchers            Publicity  52
7                       Students             Publicity  29
8             Non-research Staff             Publicity  74
9                        Faculty       Containerization  54
10 Postdocs and Staff Researchers       Containerization  54
11                      Students       Containerization  28
12            Non-research Staff       Containerization  77
13                       Faculty     Documentation help  56
14 Postdocs and Staff Researchers     Documentation help  53
15                      Students     Documentation help  33
16            Non-research Staff     Documentation help  84
17                       Faculty   A learning community  57
18 Postdocs and Staff Researchers   A learning community  53
19                      Students   A learning community  33
20            Non-research Staff   A learning community  85
21                       Faculty         Event planning  54
22 Postdocs and Staff Researchers         Event planning  52
23                      Students         Event planning  31
24            Non-research Staff         Event planning  75
25                       Faculty     Mentoring programs  55
26 Postdocs and Staff Researchers     Mentoring programs  50
27                      Students     Mentoring programs  33
28            Non-research Staff     Mentoring programs  77
29                       Faculty              Education  57
30 Postdocs and Staff Researchers              Education  52
31                      Students              Education  33
32            Non-research Staff              Education  82
33                       Faculty          Legal support  55
34 Postdocs and Staff Researchers          Legal support  52
35                      Students          Legal support  31
36            Non-research Staff          Legal support  80
37                       Faculty  Industry partnerships  56
38 Postdocs and Staff Researchers  Industry partnerships  49
39                      Students  Industry partnerships  33
40            Non-research Staff  Industry partnerships  70
41                       Faculty  Sustainability grants  57
42 Postdocs and Staff Researchers  Sustainability grants  53
43                      Students  Sustainability grants  32
44            Non-research Staff  Sustainability grants  72
45                       Faculty   Help finding funding  54
46 Postdocs and Staff Researchers   Help finding funding  51
47                      Students   Help finding funding  31
```

```
48            Non-research Staff   Help finding funding    72
```

It appears that non-research staff are weighted more heavily, and students less so, presumably because there are a lot of observations for that group and not many for the other, respectively.

```r
sapply(
  c(
    "Students",
    "Non-research Staff",
    "Postdocs and Staff Researchers",
    "Faculty"
  ),
  function(x) {
    nrow(subset(combined, job_category == x))
  }
)
```

```
                    Students                 Non-research Staff
                         380                                928
Postdocs and Staff Researchers                           Faculty
                         626                                668
```

First, let's explore the outcomes with different weighting schemes. I'm not cherry picking here, I'm just trying to understand the options. Let's calculate estimated marginal means for each solution, while holding job category constant. These will be really rough estimates, since we're averaging all the job categories, either equally or in proportion to their sample sizes.

(Here's a somewhat helpful explanation of weights in emmeans: https://stackoverflow.com/questions/66748520/w is-the-difference-between-weights-cell-and-weights-proportional-in-r-pa)

```r
# code copied from https://cran.r-project.org/web/packages/emmeans/vignettes/messy-data.html
sapply(c("equal", "prop", "outer", "cells", "flat"), \(w)
    emmeans(fit1b, ~ solution, weights = w) |> predict()) |> head()
```

```
NOTE: Results may be misleading due to involvement in interactions
NOTE: Results may be misleading due to involvement in interactions
NOTE: Results may be misleading due to involvement in interactions
NOTE: Results may be misleading due to involvement in interactions
NOTE: Results may be misleading due to involvement in interactions
```

```
          equal       prop      outer       cells       flat
[1,]   1.37546661  1.1934942  1.1934942  1.1935455  1.37546661
[2,]   0.59148638  0.3743983  0.3743983  0.3738146  0.59148638
[3,]   0.03657354 -0.1227918 -0.1227918 -0.1411864  0.03657354
[4,]   0.44431303  0.3475157  0.3475157  0.3487806  0.44431303
[5,]   0.39495919  0.3683255  0.3683255  0.3802930  0.39495919
[6,]  -0.19609423 -0.3253567 -0.3253567 -0.3217714 -0.19609423
```

We only get two sets of estimates: equal/flat gives us the estimates where all means are given equal weight. Prop, outer, and cells give us another set of estimates, where each prediction is given the same weight as occurs in the model. At least, I think that's how it works. Let's do a sanity check. First, let's look at the average ratings by job category (our weighting scheme here doesn't matter, because we're splitting it up by job, not averaging over job).

```
summary(emmeans(fit1b, ~ solution | job_category, mode="mean.class")) %>%
 arrange(desc(mean.class))
```

```
job_category = Faculty:
 solution              mean.class     SE  df asymp.LCL asymp.UCL
 Sustainability grants       2.81 0.0648 Inf      2.68      2.93
 Help finding funding        2.67 0.0898 Inf      2.50      2.85
 Computing environments      2.35 0.1170 Inf      2.12      2.58
 Publicity                   2.12 0.1250 Inf      1.87      2.36
 Industry partnerships       2.11 0.1240 Inf      1.87      2.35
 Containerization            1.97 0.1250 Inf      1.73      2.22
 Legal support               1.93 0.1190 Inf      1.70      2.16
 Documentation help          1.92 0.1220 Inf      1.68      2.16
 A learning community        1.79 0.1160 Inf      1.56      2.02
 Education                   1.75 0.1190 Inf      1.52      1.98
 Event planning              1.70 0.1190 Inf      1.47      1.93
 Mentoring programs          1.66 0.1150 Inf      1.44      1.89

job_category = Postdocs and Staff Researchers:
 solution              mean.class     SE  df asymp.LCL asymp.UCL
 Sustainability grants       2.79 0.0699 Inf      2.65      2.93
 Help finding funding        2.66 0.0929 Inf      2.47      2.84
 Publicity                   2.38 0.1180 Inf      2.14      2.61
 Computing environments      2.34 0.1230 Inf      2.10      2.58
 Documentation help          2.24 0.1230 Inf      2.00      2.49
 Industry partnerships       2.22 0.1280 Inf      1.97      2.47
 Education                   2.15 0.1240 Inf      1.91      2.40
 A learning community        2.14 0.1210 Inf      1.91      2.38
```

25

```
Legal support                    2.11 0.1260 Inf      1.86      2.36
Mentoring programs               2.02 0.1270 Inf      1.77      2.27
Event planning                   2.01 0.1250 Inf      1.76      2.26
Containerization                 1.94 0.1220 Inf      1.70      2.18

job_category = Students:
 solution                mean.class      SE  df asymp.LCL asymp.UCL
 Sustainability grants         2.97 0.0250 Inf      2.92      3.02
 Help finding funding          2.84 0.0743 Inf      2.70      2.99
 Computing environments        2.80 0.0877 Inf      2.62      2.97
 Industry partnerships         2.59 0.1310 Inf      2.33      2.85
 Publicity                     2.52 0.1440 Inf      2.23      2.80
 Mentoring programs            2.42 0.1450 Inf      2.13      2.70
 Education                     2.41 0.1490 Inf      2.12      2.70
 Legal support                 2.40 0.1500 Inf      2.10      2.69
 Documentation help            2.39 0.1510 Inf      2.09      2.68
 A learning community          2.35 0.1530 Inf      2.05      2.65
 Containerization              2.34 0.1610 Inf      2.02      2.66
 Event planning                2.22 0.1640 Inf      1.89      2.54

job_category = Non-research Staff:
 solution                mean.class      SE  df asymp.LCL asymp.UCL
 Sustainability grants         2.50 0.0922 Inf      2.32      2.68
 Help finding funding          2.34 0.0992 Inf      2.15      2.53
 Computing environments        2.32 0.0965 Inf      2.14      2.51
 A learning community          2.28 0.0930 Inf      2.10      2.46
 Legal support                 2.18 0.0973 Inf      1.99      2.37
 Education                     2.13 0.0986 Inf      1.93      2.32
 Documentation help            2.08 0.0964 Inf      1.89      2.27
 Mentoring programs            2.08 0.0991 Inf      1.88      2.27
 Industry partnerships         1.91 0.1050 Inf      1.71      2.12
 Publicity                     1.82 0.1010 Inf      1.62      2.01
 Event planning                1.79 0.1010 Inf      1.60      1.99
 Containerization              1.79 0.1010 Inf      1.59      1.99

Confidence level used: 0.95
```

Here, we see that "a learning community" is more popular among non-research staff than among other groups. So, we expect that if all groups are weighted equally, "a learning community" will be less popular than if we weight the means by sample size.

Hmm. I'm not sure why the following commands fail when we include mode="mean.class". It says no weighting information is given. Maybe it's just not possible to estimate the mean of

the underlying probability distribution AND weight that mean at the same time?

```
summary(emmeans(fit1b, ~ solution, weights = "equal")) %>%
  arrange(desc(emmean))
```

NOTE: Results may be misleading due to involvement in interactions

```
solution                emmean    SE  df asymp.LCL asymp.UCL
Sustainability grants   2.8656 0.262 Inf    2.3524     3.379
Help finding funding    1.9991 0.206 Inf    1.5959     2.402
Computing environments  1.3755 0.193 Inf    0.9968     1.754
Industry partnerships   0.6028 0.185 Inf    0.2394     0.966
Publicity               0.5915 0.185 Inf    0.2288     0.954
Documentation help      0.4443 0.179 Inf    0.0940     0.795
Legal support           0.4349 0.178 Inf    0.0858     0.784
A learning community    0.3950 0.175 Inf    0.0523     0.738
Education               0.3087 0.178 Inf   -0.0408     0.658
Mentoring programs      0.1299 0.177 Inf   -0.2176     0.477
Containerization        0.0366 0.183 Inf   -0.3214     0.395
Event planning         -0.1961 0.182 Inf   -0.5523     0.160
```

Results are averaged over the levels of: job_category
Confidence level used: 0.95

```
summary(emmeans(fit1b, ~ solution, weights = "prop")) %>%
  arrange(desc(emmean))
```

NOTE: Results may be misleading due to involvement in interactions

```
solution                emmean    SE  df asymp.LCL asymp.UCL
Sustainability grants    2.525 0.216 Inf    2.1017    2.9481
Help finding funding     1.787 0.187 Inf    1.4195    2.1536
Computing environments   1.193 0.176 Inf    0.8476    1.5394
Industry partnerships    0.393 0.175 Inf    0.0501    0.7352
Publicity                0.374 0.173 Inf    0.0356    0.7132
A learning community     0.368 0.163 Inf    0.0479    0.6888
Legal support            0.367 0.167 Inf    0.0396    0.6951
Documentation help       0.348 0.167 Inf    0.0199    0.6751
Education                0.216 0.168 Inf   -0.1131    0.5446
Mentoring programs       0.023 0.168 Inf   -0.3057    0.3517
```

```
Containerization            -0.123 0.171 Inf    -0.4586     0.2130
Event planning              -0.325 0.171 Inf    -0.6610     0.0103
```

```
Results are averaged over the levels of: job_category
Confidence level used: 0.95
```

Indeed, when we use the default weighting of "equal", "A learning community" is #8, but with "prop" weighting, it rises to #6. So now we know what the weights do.

In fact, the more that I think about it, the more I feel like we shouldn't even report the global emms–just emms by job. It may do more harm than good to average over a factor that we've already established is important. So let's look at emms by job.

```r
# This yields the same results: emmeans(fit1b, ~ solution | job_category, mode = "mean.class"
emm <- summary(emmeans(fit1b, ~ solution * job_category, mode = "mean.class"))
emm
```

```
solution              job_category                  mean.class     SE  df
Computing environments Faculty                            2.35 0.1170 Inf
Publicity              Faculty                            2.12 0.1250 Inf
Containerization       Faculty                            1.97 0.1250 Inf
Documentation help     Faculty                            1.92 0.1220 Inf
A learning community   Faculty                            1.79 0.1160 Inf
Event planning         Faculty                            1.70 0.1190 Inf
Mentoring programs     Faculty                            1.66 0.1150 Inf
Education              Faculty                            1.75 0.1190 Inf
Legal support          Faculty                            1.93 0.1190 Inf
Industry partnerships  Faculty                            2.11 0.1240 Inf
Sustainability grants  Faculty                            2.81 0.0648 Inf
Help finding funding   Faculty                            2.67 0.0898 Inf
Computing environments Postdocs and Staff Researchers     2.34 0.1230 Inf
Publicity              Postdocs and Staff Researchers     2.38 0.1180 Inf
Containerization       Postdocs and Staff Researchers     1.94 0.1220 Inf
Documentation help     Postdocs and Staff Researchers     2.24 0.1230 Inf
A learning community   Postdocs and Staff Researchers     2.14 0.1210 Inf
Event planning         Postdocs and Staff Researchers     2.01 0.1250 Inf
Mentoring programs     Postdocs and Staff Researchers     2.02 0.1270 Inf
Education              Postdocs and Staff Researchers     2.15 0.1240 Inf
Legal support          Postdocs and Staff Researchers     2.11 0.1260 Inf
Industry partnerships  Postdocs and Staff Researchers     2.22 0.1280 Inf
Sustainability grants  Postdocs and Staff Researchers     2.79 0.0699 Inf
Help finding funding   Postdocs and Staff Researchers     2.66 0.0929 Inf
```

```
Computing environments Students                      2.80 0.0877 Inf
Publicity               Students                      2.52 0.1440 Inf
Containerization        Students                      2.34 0.1610 Inf
Documentation help      Students                      2.39 0.1510 Inf
A learning community    Students                      2.35 0.1530 Inf
Event planning          Students                      2.22 0.1640 Inf
Mentoring programs      Students                      2.42 0.1450 Inf
Education               Students                      2.41 0.1490 Inf
Legal support           Students                      2.40 0.1500 Inf
Industry partnerships   Students                      2.59 0.1310 Inf
Sustainability grants   Students                      2.97 0.0250 Inf
Help finding funding    Students                      2.84 0.0743 Inf
Computing environments Non-research Staff             2.32 0.0965 Inf
Publicity               Non-research Staff             1.82 0.1010 Inf
Containerization        Non-research Staff             1.79 0.1010 Inf
Documentation help      Non-research Staff             2.08 0.0964 Inf
A learning community    Non-research Staff             2.28 0.0930 Inf
Event planning          Non-research Staff             1.79 0.1010 Inf
Mentoring programs      Non-research Staff             2.08 0.0991 Inf
Education               Non-research Staff             2.13 0.0986 Inf
Legal support           Non-research Staff             2.18 0.0973 Inf
Industry partnerships   Non-research Staff             1.91 0.1050 Inf
Sustainability grants   Non-research Staff             2.50 0.0922 Inf
Help finding funding    Non-research Staff             2.34 0.0992 Inf
asymp.LCL asymp.UCL
     2.12      2.58
     1.87      2.36
     1.73      2.22
     1.68      2.16
     1.56      2.02
     1.47      1.93
     1.44      1.89
     1.52      1.98
     1.70      2.16
     1.87      2.35
     2.68      2.93
     2.50      2.85
     2.10      2.58
     2.14      2.61
     1.70      2.18
     2.00      2.49
     1.91      2.38
     1.76      2.26
```

```
1.77      2.27
1.91      2.40
1.86      2.36
1.97      2.47
2.65      2.93
2.47      2.84
2.62      2.97
2.23      2.80
2.02      2.66
2.09      2.68
2.05      2.65
1.89      2.54
2.13      2.70
2.12      2.70
2.10      2.69
2.33      2.85
2.92      3.02
2.70      2.99
2.14      2.51
1.62      2.01
1.59      1.99
1.89      2.27
2.10      2.46
1.60      1.99
1.88      2.27
1.93      2.32
1.99      2.37
1.71      2.12
2.32      2.68
2.15      2.53
```

```
Confidence level used: 0.95
```

Plot emms

Plot the results.

```
emm_clean <- emm %>%
  rename(mean = mean.class,
         lwr  = asymp.LCL,
         upr  = asymp.UCL) %>%
```

```
  mutate(across(c(mean, lwr, upr), as.numeric))

# Use a common ordering of solutions (here, overall mean w equal weighting)
solns_ordered <- summary(emmeans(fit1b, ~ solution, weights = "equal")) %>%
  arrange(emmean) %>% # don't do desc() bc these will be flipped later w coord_flip()
  pull(solution) %>%
  as.character()
```

NOTE: Results may be misleading due to involvement in interactions

```
emm_clean <- emm_clean %>%
  mutate(solution = factor(solution, levels = solns_ordered))

make_plot <- function(df, jc) {
  ggplot(filter(df, job_category == jc),
         aes(x = solution, y = mean)) +
    geom_errorbar(aes(ymin = lwr, ymax = upr),
                  width = .15, linewidth = .4) +
    geom_point(size = 3) +
    ylim(c(1, 3)) +
    labs(title = jc, x = NULL, y = "Estimated mean rating (0-3)") +
    coord_flip() +                      # solutions run down the y-axis
    theme(
      plot.title = element_text(face = "bold"),
      axis.text.x = element_text(
        size = 12
      ),
      axis.text.y = element_text(
        size = 12
        ),
      panel.background = element_blank(),
      panel.grid =
        element_line(
          linetype = "solid",
          color = "gray90"
          ),
      plot.margin = unit(c(0.3, 0.3, 0.3, 0.3), "cm")
    )
}

plots <- lapply(unique(emm_clean$job_category),
```
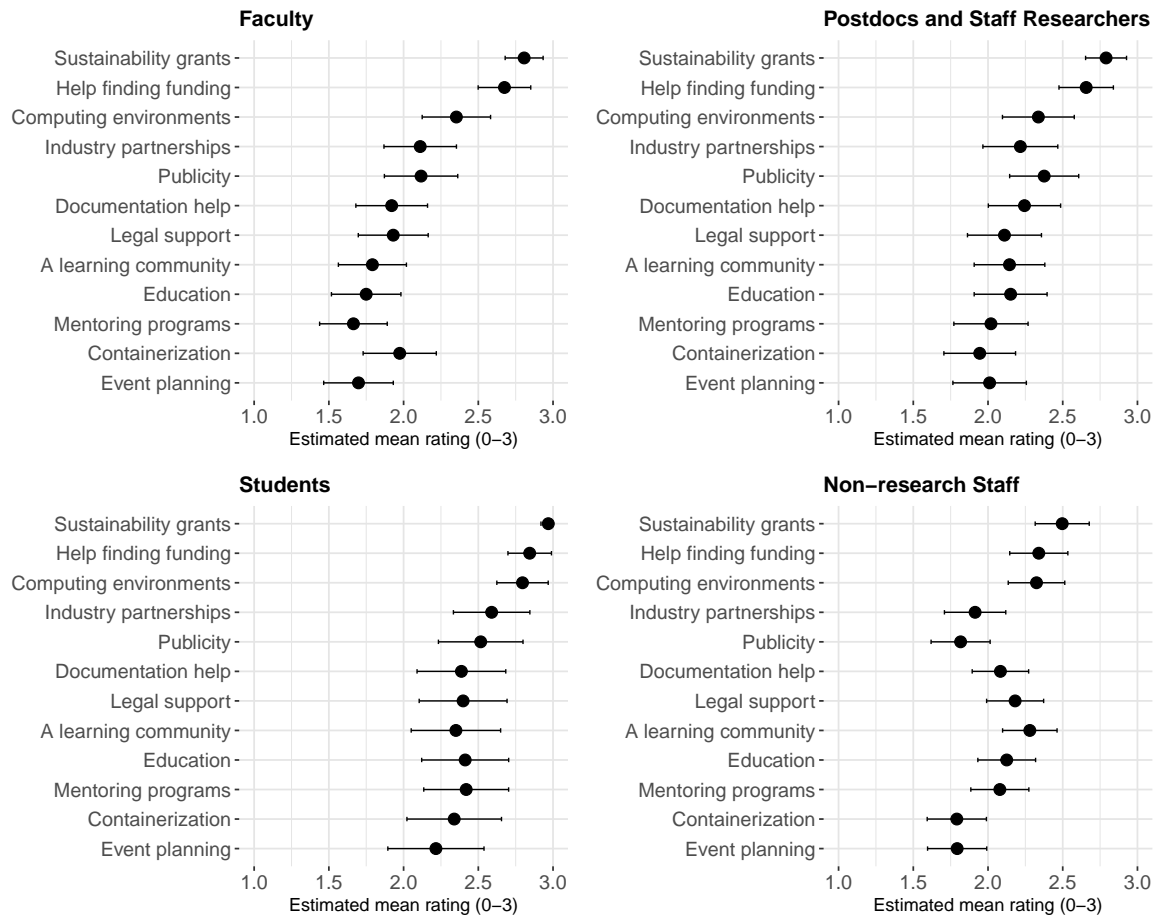
```
              make_plot, df = emm_clean)

composite_plot <- wrap_plots(plots, ncol = 2)

composite_plot
```



```
save_plot("solns_points.tiff", 12, 10, p=composite_plot)
```

I find it very surprising that "a learning community" ranked so low. Let's look at the rating distribution for each job category, for this solution, from the observed sample.
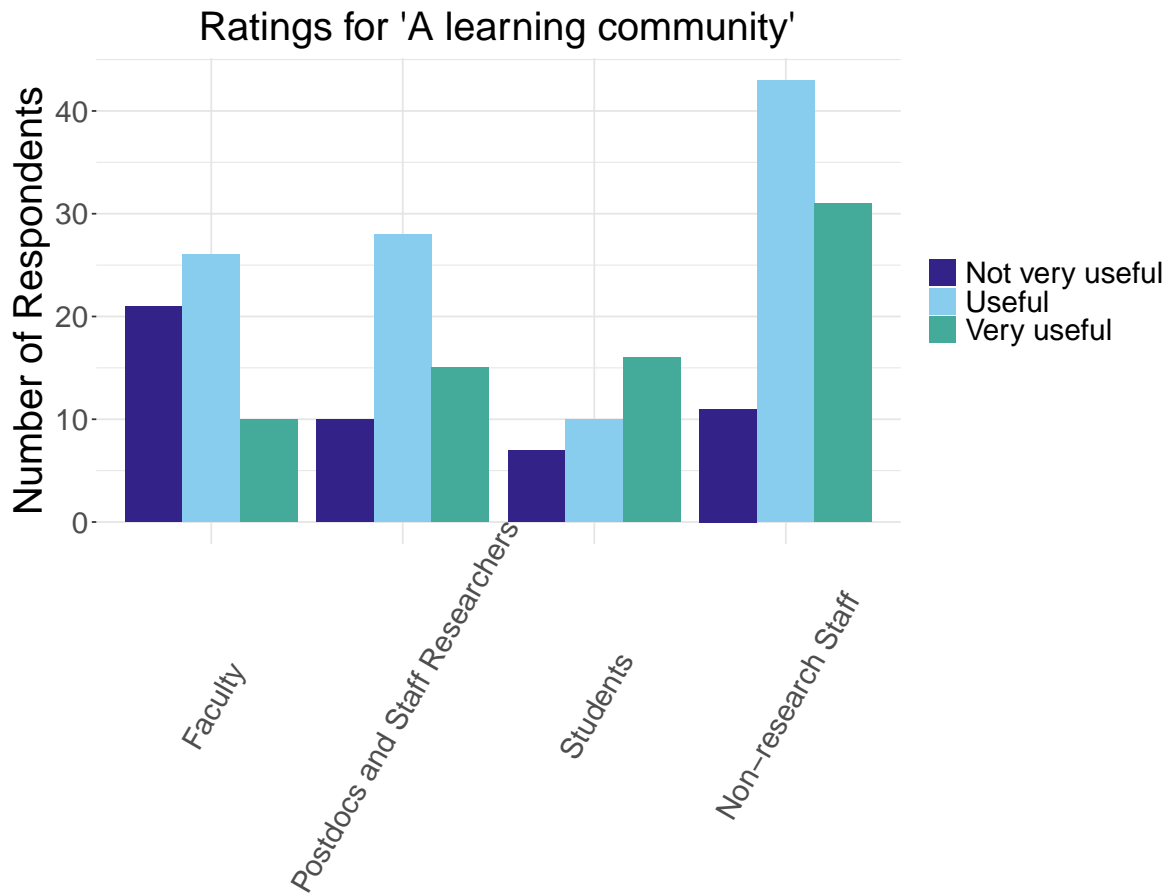
```
learning_ratings <- grouped_bar_chart(
  df = subset(combined, solution=="A learning community"),
  x_var = "job_category",
```

```
    fill_var = "utility",
    title = "Ratings for 'A learning community'")
learning_ratings
```

Ratings for 'A learning community'


```
save_plot("solns_learning_comm.tiff", 12, 10, p=learning_ratings)
```

Ok, it's a messy plot but whatever. It shows that a lot of non-research staff selected "useful" or "very useful".

Pairwise comparisons and p-values

```r
emm_job <- emmeans(fit1b, ~ job_category * solution, mode = "mean.class")
by_job <- summary(
  pairs(emm_job, by = "job_category"),
  infer = TRUE # infer CIs
)
by_job
```

```
job_category = Faculty:
 contrast                                        estimate      SE  df asymp.LCL
 Computing environments - Publicity               0.23622 0.1430 Inf  -0.22988
 Computing environments - Containerization        0.37914 0.1420 Inf  -0.08558
 Computing environments - Documentation help      0.43280 0.1400 Inf  -0.02510
 Computing environments - A learning community    0.56189 0.1350 Inf   0.12029
 Computing environments - Event planning          0.65494 0.1380 Inf   0.20288
 Computing environments - Mentoring programs      0.68885 0.1360 Inf   0.24467
 Computing environments - Education               0.60345 0.1380 Inf   0.15348
 Computing environments - Legal support           0.42245 0.1370 Inf  -0.02656
 Computing environments - Industry partnerships   0.24196 0.1410 Inf  -0.21914
 Computing environments - Sustainability grants  -0.45350 0.1170 Inf  -0.83629
 Computing environments - Help finding funding   -0.32175 0.1250 Inf  -0.72992
 Publicity - Containerization                     0.14292 0.1470 Inf  -0.33727
 Publicity - Documentation help                   0.19659 0.1450 Inf  -0.27689
 Publicity - A learning community                 0.32568 0.1400 Inf  -0.13345
 Publicity - Event planning                       0.41872 0.1430 Inf  -0.04988
 Publicity - Mentoring programs                   0.45263 0.1410 Inf  -0.00909
 Publicity - Education                            0.36723 0.1430 Inf  -0.10032
 Publicity - Legal support                        0.18624 0.1420 Inf  -0.27892
 Publicity - Industry partnerships                0.00574 0.1460 Inf  -0.47260
 Publicity - Sustainability grants               -0.68972 0.1250 Inf  -1.09721
 Publicity - Help finding funding                -0.55796 0.1320 Inf  -0.98793
 Containerization - Documentation help            0.05366 0.1440 Inf  -0.41846
 Containerization - A learning community          0.18276 0.1400 Inf  -0.27471
 Containerization - Event planning                0.27580 0.1430 Inf  -0.19076
 Containerization - Mentoring programs            0.30971 0.1410 Inf  -0.14988
 Containerization - Education                     0.22431 0.1420 Inf  -0.24104
 Containerization - Legal support                 0.04332 0.1420 Inf  -0.41962
 Containerization - Industry partnerships        -0.13718 0.1460 Inf  -0.61350
 Containerization - Sustainability grants        -0.83264 0.1240 Inf  -1.23945
 Containerization - Help finding funding         -0.70088 0.1310 Inf  -1.12970
 Documentation help - A learning community        0.12909 0.1380 Inf  -0.32113
 Documentation help - Event planning              0.22214 0.1410 Inf  -0.23742
```

```
Documentation help - Mentoring programs         0.25605 0.1390 Inf  -0.19683
Documentation help - Education                  0.17065 0.1400 Inf  -0.28826
Documentation help - Legal support             -0.01035 0.1400 Inf  -0.46685
Documentation help - Industry partnerships     -0.19084 0.1440 Inf  -0.66074
Documentation help - Sustainability grants     -0.88630 0.1220 Inf  -1.28524
Documentation help - Help finding funding      -0.75455 0.1290 Inf  -1.17602
A learning community - Event planning           0.09305 0.1360 Inf  -0.35088
A learning community - Mentoring programs       0.12696 0.1340 Inf  -0.30944
A learning community - Education                0.04156 0.1350 Inf  -0.40053
A learning community - Legal support           -0.13944 0.1350 Inf  -0.58077
A learning community - Industry partnerships   -0.31994 0.1390 Inf  -0.77466
A learning community - Sustainability grants   -1.01539 0.1160 Inf  -1.39519
A learning community - Help finding funding    -0.88364 0.1240 Inf  -1.28815
Event planning - Mentoring programs             0.03391 0.1360 Inf  -0.41124
Event planning - Education                     -0.05149 0.1380 Inf  -0.50354
Event planning - Legal support                 -0.23249 0.1380 Inf  -0.68353
Event planning - Industry partnerships         -0.41298 0.1420 Inf  -0.87685
Event planning - Sustainability grants         -1.10844 0.1200 Inf  -1.49918
Event planning - Help finding funding          -0.97669 0.1270 Inf  -1.39104
Mentoring programs - Education                 -0.08540 0.1360 Inf  -0.52933
Mentoring programs - Legal support             -0.26640 0.1360 Inf  -0.70986
Mentoring programs - Industry partnerships     -0.44689 0.1400 Inf  -0.90361
Mentoring programs - Sustainability grants     -1.14235 0.1160 Inf  -1.52291
Mentoring programs - Help finding funding      -1.01060 0.1240 Inf  -1.41596
Education - Legal support                      -0.18100 0.1380 Inf  -0.63049
Education - Industry partnerships              -0.36149 0.1420 Inf  -0.82408
Education - Sustainability grants              -1.05695 0.1190 Inf  -1.44559
Education - Help finding funding               -0.92520 0.1260 Inf  -1.33849
Legal support - Industry partnerships          -0.18049 0.1410 Inf  -0.64123
Legal support - Sustainability grants          -0.87595 0.1190 Inf  -1.26519
Legal support - Help finding funding           -0.74420 0.1260 Inf  -1.15604
Industry partnerships - Sustainability grants  -0.69546 0.1230 Inf  -1.09855
Industry partnerships - Help finding funding   -0.56370 0.1300 Inf  -0.98864
Sustainability grants - Help finding funding    0.13175 0.0962 Inf  -0.18273
asymp.UCL z.ratio p.value
  0.70231   1.656  0.8878
  0.84386   2.666  0.2433
  0.89070   3.089  0.0849
  1.00349   4.158  0.0019
  1.10700   4.735  0.0001
  1.13303   5.068  <.0001
  1.05342   4.383  0.0007
  0.87146   3.075  0.0883
```

```
 0.70305    1.715   0.8618
-0.07071   -3.872   0.0061
 0.08643   -2.576   0.2933
 0.62311    0.973   0.9982
 0.67006    1.357   0.9713
 0.78480    2.318   0.4634
 0.88732    2.920   0.1336
 0.91436    3.204   0.0608
 0.83478    2.567   0.2987
 0.65139    1.308   0.9783
 0.48408    0.039   1.0000
-0.28222   -5.531   <.0001
-0.12800   -4.241   0.0013
 0.52579    0.371   1.0000
 0.64022    1.306   0.9786
 0.74237    1.932   0.7393
 0.76931    2.202   0.5479
 0.68966    1.575   0.9182
 0.50625    0.306   1.0000
 0.33914   -0.941   0.9987
-0.42582   -6.689   <.0001
-0.27207   -5.341   <.0001
 0.57932    0.937   0.9987
 0.68170    1.580   0.9167
 0.70892    1.848   0.7914
 0.62955    1.215   0.9879
 0.44615   -0.074   1.0000
 0.27906   -1.327   0.9757
-0.48737   -7.260   <.0001
-0.33308   -5.851   <.0001
 0.53698    0.685   0.9999
 0.56335    0.951   0.9986
 0.48365    0.307   1.0000
 0.30189   -1.033   0.9970
 0.13479   -2.299   0.4770
-0.63560   -8.737   <.0001
-0.47914   -7.139   <.0001
 0.47906    0.249   1.0000
 0.40056   -0.372   1.0000
 0.21855   -1.685   0.8757
 0.05088   -2.910   0.1373
-0.71770   -9.271   <.0001
-0.56234   -7.703   <.0001
```

```
   0.35853   -0.629   1.0000
   0.17706   -1.963   0.7186
   0.00983   -3.198   0.0619
  -0.76179   -9.810   <.0001
  -0.60523   -8.147   <.0001
   0.26850   -1.316   0.9773
   0.10110   -2.554   0.3065
  -0.66831   -8.888   <.0001
  -0.51190   -7.316   <.0001
   0.28024   -1.280   0.9817
  -0.48671   -7.354   <.0001
  -0.33236   -5.905   <.0001
  -0.29236   -5.638   <.0001
  -0.13876   -4.335   0.0009
   0.44624    1.369   0.9693
```

job_category = Postdocs and Staff Researchers:

contrast	estimate	SE	df	asymp.LCL
Computing environments - Publicity	-0.03891	0.1410	Inf	-0.49862
Computing environments - Containerization	0.39238	0.1430	Inf	-0.07335
Computing environments - Documentation help	0.09297	0.1440	Inf	-0.37722
Computing environments - A learning community	0.19321	0.1410	Inf	-0.26743
Computing environments - Event planning	0.32620	0.1450	Inf	-0.14816
Computing environments - Mentoring programs	0.31718	0.1460	Inf	-0.16027
Computing environments - Education	0.18558	0.1440	Inf	-0.28606
Computing environments - Legal support	0.22683	0.1460	Inf	-0.25028
Computing environments - Industry partnerships	0.12057	0.1480	Inf	-0.36191
Computing environments - Sustainability grants	-0.45301	0.1230	Inf	-0.85504
Computing environments - Help finding funding	-0.31995	0.1300	Inf	-0.74384
Publicity - Containerization	0.43129	0.1390	Inf	-0.02306
Publicity - Documentation help	0.13188	0.1400	Inf	-0.32634
Publicity - A learning community	0.23212	0.1370	Inf	-0.21662
Publicity - Event planning	0.36511	0.1420	Inf	-0.09754
Publicity - Mentoring programs	0.35609	0.1430	Inf	-0.10968
Publicity - Education	0.22449	0.1410	Inf	-0.23507
Publicity - Legal support	0.26574	0.1420	Inf	-0.19929
Publicity - Industry partnerships	0.15948	0.1440	Inf	-0.31116
Publicity - Sustainability grants	-0.41410	0.1190	Inf	-0.80181
Publicity - Help finding funding	-0.28104	0.1260	Inf	-0.69134
Containerization - Documentation help	-0.29941	0.1420	Inf	-0.76383
Containerization - A learning community	-0.19917	0.1390	Inf	-0.65311
Containerization - Event planning	-0.06618	0.1430	Inf	-0.53314
Containerization - Mentoring programs	-0.07520	0.1440	Inf	-0.54660

```
Containerization - Education                              -0.20680 0.1420 Inf  -0.67182
Containerization - Legal support                          -0.16554 0.1440 Inf  -0.63629
Containerization - Industry partnerships                  -0.27181 0.1460 Inf  -0.74854
Containerization - Sustainability grants                  -0.84539 0.1220 Inf  -1.24474
Containerization - Help finding funding                   -0.71233 0.1290 Inf  -1.13265
Documentation help - A learning community                  0.10025 0.1410 Inf  -0.35902
Documentation help - Event planning                        0.23323 0.1450 Inf  -0.23905
Documentation help - Mentoring programs                    0.22422 0.1450 Inf  -0.25126
Documentation help - Education                             0.09261 0.1440 Inf  -0.37753
Documentation help - Legal support                         0.13387 0.1450 Inf  -0.34160
Documentation help - Industry partnerships                 0.02760 0.1470 Inf  -0.45309
Documentation help - Sustainability grants                -0.54598 0.1230 Inf  -0.94934
Documentation help - Help finding funding                 -0.41292 0.1300 Inf  -0.83713
A learning community - Event planning                      0.13298 0.1420 Inf  -0.32949
A learning community - Mentoring programs                  0.12397 0.1430 Inf  -0.34173
A learning community - Education                           -0.00763 0.1410 Inf  -0.46756
A learning community - Legal support                       0.03362 0.1420 Inf  -0.43192
A learning community - Industry partnerships              -0.07265 0.1440 Inf  -0.54438
A learning community - Sustainability grants              -0.64623 0.1200 Inf  -1.03982
A learning community - Help finding funding               -0.51317 0.1270 Inf  -0.92776
Event planning - Mentoring programs                       -0.00902 0.1470 Inf  -0.48789
Event planning - Education                                -0.14062 0.1450 Inf  -0.61387
Event planning - Legal support                            -0.09936 0.1460 Inf  -0.57802
Event planning - Industry partnerships                    -0.20563 0.1480 Inf  -0.69057
Event planning - Sustainability grants                    -0.77921 0.1250 Inf  -1.18850
Event planning - Help finding funding                     -0.64615 0.1310 Inf  -1.07587
Mentoring programs - Education                            -0.13160 0.1460 Inf  -0.60816
Mentoring programs - Legal support                        -0.09035 0.1480 Inf  -0.57291
Mentoring programs - Industry partnerships                -0.19661 0.1490 Inf  -0.68440
Mentoring programs - Sustainability grants                -0.77019 0.1270 Inf  -1.18362
Mentoring programs - Help finding funding                 -0.63714 0.1330 Inf  -1.07017
Education - Legal support                                  0.04125 0.1460 Inf  -0.43563
Education - Industry partnerships                         -0.06501 0.1480 Inf  -0.54806
Education - Sustainability grants                         -0.63859 0.1240 Inf  -1.04495
Education - Help finding funding                          -0.50553 0.1310 Inf  -0.93239
Legal support - Industry partnerships                     -0.10627 0.1490 Inf  -0.59279
Legal support - Sustainability grants                     -0.67985 0.1260 Inf  -1.09192
Legal support - Help finding funding                      -0.54679 0.1320 Inf  -0.97917
Industry partnerships - Sustainability grants             -0.57358 0.1280 Inf  -0.99062
Industry partnerships - Help finding funding              -0.44052 0.1340 Inf  -0.87721
Sustainability grants - Help finding funding               0.13306 0.0996 Inf  -0.19235
asymp.UCL z.ratio p.value
   0.42080  -0.277  1.0000
```

```
 0.85811    2.753   0.2004
 0.56316    0.646   1.0000
 0.65385    1.371   0.9691
 0.80056    2.247   0.5149
 0.79463    2.171   0.5709
 0.65722    1.286   0.9810
 0.70394    1.554   0.9253
 0.60305    0.817   0.9997
-0.05098   -3.682   0.0124
 0.10393   -2.467   0.3611
 0.88564    3.102   0.0817
 0.59010    0.941   0.9987
 0.68086    1.690   0.8730
 0.82776    2.579   0.2915
 0.82187    2.498   0.3407
 0.68405    1.596   0.9109
 0.73078    1.868   0.7796
 0.63012    1.107   0.9944
-0.02639   -3.490   0.0243
 0.12926   -2.238   0.5213
 0.16500   -2.107   0.6178
 0.25478   -1.434   0.9570
 0.40078   -0.463   1.0000
 0.39621   -0.521   1.0000
 0.25823   -1.453   0.9527
 0.30520   -1.149   0.9924
 0.20492   -1.863   0.7821
-0.44604   -6.918   <.0001
-0.29201   -5.538   <.0001
 0.55952    0.713   0.9999
 0.70551    1.614   0.9045
 0.69969    1.541   0.9292
 0.56275    0.644   1.0000
 0.60933    0.920   0.9989
 0.50829    0.188   1.0000
-0.14261   -4.423   0.0006
 0.01129   -3.181   0.0650
 0.59546    0.940   0.9987
 0.58967    0.870   0.9994
 0.45229   -0.054   1.0000
 0.49916    0.236   1.0000
 0.39909   -0.503   1.0000
-0.25263   -5.366   <.0001
```

```
-0.09857  -4.045  0.0031
 0.46986  -0.062  1.0000
 0.33263  -0.971  0.9983
 0.37930  -0.678  0.9999
 0.27931  -1.386  0.9665
-0.36992  -6.222  <.0001
-0.21644  -4.914  0.0001
 0.34496  -0.902  0.9991
 0.39221  -0.612  1.0000
 0.29117  -1.317  0.9771
-0.35677  -6.088  <.0001
-0.20410  -4.808  0.0001
 0.51814   0.283  1.0000
 0.41803  -0.440  1.0000
-0.23224  -5.136  <.0001
-0.07867  -3.870  0.0061
 0.38026  -0.714  0.9999
-0.26777  -5.392  <.0001
-0.11441  -4.133  0.0021
-0.15654  -4.495  0.0004
-0.00384  -3.297  0.0457
 0.45846   1.336  0.9745
```

job_category = Students:

contrast	estimate	SE	df	asymp.LCL
Computing environments - Publicity	0.27963	0.1470	Inf	-0.19968
Computing environments - Containerization	0.45699	0.1610	Inf	-0.07031
Computing environments - Documentation help	0.40891	0.1510	Inf	-0.08603
Computing environments - A learning community	0.44565	0.1520	Inf	-0.05189
Computing environments - Event planning	0.57943	0.1630	Inf	0.04616
Computing environments - Mentoring programs	0.37691	0.1450	Inf	-0.09751
Computing environments - Education	0.38367	0.1490	Inf	-0.10221
Computing environments - Legal support	0.39743	0.1500	Inf	-0.09311
Computing environments - Industry partnerships	0.20652	0.1350	Inf	-0.23467
Computing environments - Sustainability grants	-0.17255	0.0870	Inf	-0.45673
Computing environments - Help finding funding	-0.04811	0.0997	Inf	-0.37408
Publicity - Containerization	0.17736	0.1810	Inf	-0.41538
Publicity - Documentation help	0.12928	0.1740	Inf	-0.43929
Publicity - A learning community	0.16602	0.1740	Inf	-0.40379
Publicity - Event planning	0.29980	0.1830	Inf	-0.29832
Publicity - Mentoring programs	0.09728	0.1690	Inf	-0.45414
Publicity - Education	0.10404	0.1720	Inf	-0.45653
Publicity - Legal support	0.11780	0.1720	Inf	-0.44375

Contrast	estimate	SE	df	
Publicity - Industry partnerships	-0.07311	0.1620	Inf	-0.60292
Publicity - Sustainability grants	-0.45218	0.1420	Inf	-0.91638
Publicity - Help finding funding	-0.32774	0.1440	Inf	-0.79796
Containerization - Documentation help	-0.04808	0.1840	Inf	-0.65032
Containerization - A learning community	-0.01134	0.1850	Inf	-0.61461
Containerization - Event planning	0.12244	0.1920	Inf	-0.50535
Containerization - Mentoring programs	-0.08008	0.1790	Inf	-0.66621
Containerization - Education	-0.07332	0.1820	Inf	-0.66930
Containerization - Legal support	-0.05956	0.1830	Inf	-0.65709
Containerization - Industry partnerships	-0.25047	0.1740	Inf	-0.82050
Containerization - Sustainability grants	-0.62954	0.1590	Inf	-1.14918
Containerization - Help finding funding	-0.50510	0.1590	Inf	-1.02508
Documentation help - A learning community	0.03674	0.1760	Inf	-0.54004
Documentation help - Event planning	0.17052	0.1850	Inf	-0.43435
Documentation help - Mentoring programs	-0.03200	0.1710	Inf	-0.59105
Documentation help - Education	-0.02524	0.1740	Inf	-0.59358
Documentation help - Legal support	-0.01148	0.1750	Inf	-0.58370
Documentation help - Industry partnerships	-0.20239	0.1660	Inf	-0.74429
Documentation help - Sustainability grants	-0.58146	0.1490	Inf	-1.06798
Documentation help - Help finding funding	-0.45702	0.1490	Inf	-0.94547
A learning community - Event planning	0.13378	0.1850	Inf	-0.47172
A learning community - Mentoring programs	-0.06874	0.1710	Inf	-0.62883
A learning community - Education	-0.06198	0.1740	Inf	-0.63156
A learning community - Legal support	-0.04822	0.1750	Inf	-0.62149
A learning community - Industry partnerships	-0.23913	0.1660	Inf	-0.78233
A learning community - Sustainability grants	-0.61820	0.1500	Inf	-1.10859
A learning community - Help finding funding	-0.49376	0.1500	Inf	-0.98500
Event planning - Mentoring programs	-0.20252	0.1800	Inf	-0.79210
Event planning - Education	-0.19576	0.1830	Inf	-0.79397
Event planning - Legal support	-0.18200	0.1840	Inf	-0.78444
Event planning - Industry partnerships	-0.37291	0.1760	Inf	-0.94709
Event planning - Sustainability grants	-0.75198	0.1620	Inf	-1.28013
Event planning - Help finding funding	-0.62754	0.1610	Inf	-1.15528
Mentoring programs - Education	0.00676	0.1690	Inf	-0.54504
Mentoring programs - Legal support	0.02052	0.1700	Inf	-0.53514
Mentoring programs - Industry partnerships	-0.17039	0.1600	Inf	-0.69447
Mentoring programs - Sustainability grants	-0.54946	0.1420	Inf	-1.01423
Mentoring programs - Help finding funding	-0.42502	0.1430	Inf	-0.89225
Education - Legal support	0.01376	0.1730	Inf	-0.55126
Education - Industry partnerships	-0.17715	0.1630	Inf	-0.71099
Education - Sustainability grants	-0.55622	0.1460	Inf	-1.03302
Education - Help finding funding	-0.43178	0.1460	Inf	-0.91035
Legal support - Industry partnerships	-0.19091	0.1640	Inf	-0.72809

```
Legal support - Sustainability grants              -0.56998 0.1470 Inf  -1.05152
Legal support - Help finding funding               -0.44554 0.1480 Inf  -0.92848
Industry partnerships - Sustainability grants      -0.37907 0.1280 Inf  -0.79837
Industry partnerships - Help finding funding       -0.25463 0.1320 Inf  -0.68506
Sustainability grants - Help finding funding        0.12444 0.0743 Inf  -0.11849
asymp.UCL z.ratio p.value
  0.75894    1.907  0.7554
  0.98429    2.832  0.1664
  0.90385    2.700  0.2260
  0.94319    2.927  0.1313
  1.11270    3.551  0.0198
  0.85134    2.596  0.2815
  0.86955    2.581  0.2906
  0.88798    2.648  0.2530
  0.64771    1.530  0.9326
  0.11163   -1.984  0.7044
  0.27787   -0.482  1.0000
  0.77010    0.978  0.9981
  0.69785    0.743  0.9999
  0.73583    0.952  0.9985
  0.89792    1.638  0.8952
  0.64871    0.577  1.0000
  0.66461    0.607  1.0000
  0.67936    0.686  0.9999
  0.45670   -0.451  1.0000
  0.01202   -3.183  0.0646
  0.14249   -2.278  0.4926
  0.55416   -0.261  1.0000
  0.59193   -0.061  1.0000
  0.75023    0.637  1.0000
  0.50605   -0.446  1.0000
  0.52266   -0.402  1.0000
  0.53798   -0.326  1.0000
  0.31957   -1.436  0.9566
 -0.10990   -3.959  0.0043
  0.01489   -3.174  0.0663
  0.61352    0.208  1.0000
  0.77539    0.921  0.9989
  0.52705   -0.187  1.0000
  0.54311   -0.145  1.0000
  0.56075   -0.066  1.0000
  0.33952   -1.221  0.9875
 -0.09494   -3.906  0.0053
```

```
 0.03144  -3.058  0.0926
 0.73928   0.722  0.9999
 0.49136  -0.401  1.0000
 0.50761  -0.356  1.0000
 0.52506  -0.275  1.0000
 0.30407  -1.439  0.9560
-0.12781  -4.120  0.0022
-0.00251  -3.285  0.0475
 0.38706  -1.123  0.9938
 0.40246  -1.069  0.9959
 0.42045  -0.987  0.9980
 0.20127  -2.122  0.6065
-0.22383  -4.653  0.0002
-0.09980  -3.886  0.0058
 0.55856   0.040  1.0000
 0.57619   0.121  1.0000
 0.35370  -1.062  0.9961
-0.08469  -3.864  0.0063
 0.04221  -2.973  0.1165
 0.57878   0.080  1.0000
 0.35669  -1.084  0.9954
-0.07943  -3.812  0.0076
 0.04679  -2.948  0.1242
 0.34627  -1.161  0.9917
-0.08844  -3.868  0.0062
 0.03739  -3.015  0.1041
 0.04023  -2.954  0.1223
 0.17580  -1.933  0.7383
 0.36737   1.674  0.8802
```

```
job_category = Non-research Staff:
 contrast                                    estimate      SE  df asymp.LCL
 Computing environments - Publicity           0.50790 0.1160 Inf   0.12940
 Computing environments - Containerization    0.53326 0.1160 Inf   0.15404
 Computing environments - Documentation help  0.24149 0.1110 Inf  -0.12274
 Computing environments - A learning community 0.04472 0.1090 Inf  -0.31251
 Computing environments - Event planning      0.53094 0.1160 Inf   0.15130
 Computing environments - Mentoring programs  0.24534 0.1140 Inf  -0.12603
 Computing environments - Education           0.19929 0.1130 Inf  -0.17107
 Computing environments - Legal support       0.14308 0.1130 Inf  -0.22517
 Computing environments - Industry partnerships 0.41088 0.1190 Inf   0.02304
 Computing environments - Sustainability grants -0.17207 0.1120 Inf  -0.53764
 Computing environments - Help finding funding -0.01530 0.1150 Inf  -0.39174
```

```
Publicity - Containerization                       0.02537 0.1180 Inf   -0.36150
Publicity - Documentation help                    -0.26641 0.1140 Inf   -0.63998
Publicity - A learning community                  -0.46318 0.1130 Inf   -0.83184
Publicity - Event planning                         0.02305 0.1180 Inf   -0.36370
Publicity - Mentoring programs                    -0.26256 0.1160 Inf   -0.64299
Publicity - Education                             -0.30860 0.1160 Inf   -0.68870
Publicity - Legal support                         -0.36482 0.1160 Inf   -0.74243
Publicity - Industry partnerships                 -0.09702 0.1210 Inf   -0.49181
Publicity - Sustainability grants                 -0.67997 0.1150 Inf   -1.05513
Publicity - Help finding funding                  -0.52320 0.1180 Inf   -0.90843
Containerization - Documentation help             -0.29178 0.1150 Inf   -0.66655
Containerization - A learning community           -0.48855 0.1130 Inf   -0.85772
Containerization - Event planning                 -0.00232 0.1190 Inf   -0.39019
Containerization - Mentoring programs             -0.28792 0.1170 Inf   -0.66977
Containerization - Education                      -0.33397 0.1170 Inf   -0.71474
Containerization - Legal support                  -0.39019 0.1160 Inf   -0.76880
Containerization - Industry partnerships          -0.12239 0.1210 Inf   -0.51923
Containerization - Sustainability grants          -0.70533 0.1150 Inf   -1.08241
Containerization - Help finding funding           -0.54857 0.1180 Inf   -0.93571
Documentation help - A learning community         -0.19677 0.1080 Inf   -0.55004
Documentation help - Event planning                0.28946 0.1140 Inf   -0.08470
Documentation help - Mentoring programs            0.00385 0.1120 Inf   -0.36328
Documentation help - Education                    -0.04219 0.1120 Inf   -0.40785
Documentation help - Legal support                -0.09841 0.1110 Inf   -0.46157
Documentation help - Industry partnerships         0.16939 0.1170 Inf   -0.21414
Documentation help - Sustainability grants        -0.41356 0.1110 Inf   -0.77496
Documentation help - Help finding funding         -0.25679 0.1140 Inf   -0.62891
A learning community - Event planning              0.48623 0.1130 Inf    0.11765
A learning community - Mentoring programs          0.20062 0.1100 Inf   -0.16031
A learning community - Education                   0.15458 0.1100 Inf   -0.20497
A learning community - Legal support               0.09836 0.1090 Inf   -0.25785
A learning community - Industry partnerships       0.36616 0.1160 Inf   -0.01200
A learning community - Sustainability grants      -0.21679 0.1080 Inf   -0.57092
A learning community - Help finding funding       -0.06002 0.1120 Inf   -0.42594
Event planning - Mentoring programs               -0.28560 0.1170 Inf   -0.66647
Event planning - Education                        -0.33165 0.1160 Inf   -0.71207
Event planning - Legal support                    -0.38787 0.1160 Inf   -0.76541
Event planning - Industry partnerships            -0.12007 0.1210 Inf   -0.51582
Event planning - Sustainability grants            -0.70301 0.1150 Inf   -1.07868
Event planning - Help finding funding             -0.54625 0.1180 Inf   -0.93233
Mentoring programs - Education                    -0.04605 0.1140 Inf   -0.41932
Mentoring programs - Legal support                -0.10226 0.1140 Inf   -0.47335
Mentoring programs - Industry partnerships         0.16554 0.1190 Inf   -0.22360
```

```
Mentoring programs - Sustainability grants      -0.41741 0.1130 Inf  -0.78640
Mentoring programs - Help finding funding       -0.26064 0.1160 Inf  -0.63983
Education - Legal support                       -0.05622 0.1130 Inf  -0.42548
Education - Industry partnerships                0.21158 0.1190 Inf  -0.17754
Education - Sustainability grants               -0.37136 0.1130 Inf  -0.73912
Education - Help finding funding                -0.21460 0.1160 Inf  -0.59298
Legal support - Industry partnerships            0.26780 0.1190 Inf  -0.11953
Legal support - Sustainability grants           -0.31515 0.1110 Inf  -0.67901
Legal support - Help finding funding            -0.15838 0.1150 Inf  -0.53332
Industry partnerships - Sustainability grants   -0.58295 0.1180 Inf  -0.96766
Industry partnerships - Help finding funding    -0.42618 0.1210 Inf  -0.82027
Sustainability grants - Help finding funding     0.15677 0.1130 Inf  -0.21344
asymp.UCL z.ratio p.value
  0.88640    4.385  0.0007
  0.91249    4.595  0.0003
  0.60572    2.167  0.5741
  0.40195    0.409  1.0000
  0.91059    4.570  0.0003
  0.61671    2.159  0.5798
  0.56966    1.759  0.8404
  0.51132    1.270  0.9828
  0.79871    3.462  0.0268
  0.19350   -1.538  0.9301
  0.36113   -0.133  1.0000
  0.41223    0.214  1.0000
  0.10716   -2.331  0.4545
 -0.09451   -4.106  0.0024
  0.40979    0.195  1.0000
  0.11788   -2.255  0.5089
  0.07149   -2.653  0.2500
  0.01279   -3.157  0.0697
  0.29777   -0.803  0.9997
 -0.30480   -5.923  <.0001
 -0.13797   -4.438  0.0006
  0.08300   -2.544  0.3122
 -0.11937   -4.325  0.0009
  0.38555   -0.020  1.0000
  0.09393   -2.464  0.3628
  0.04680   -2.866  0.1531
 -0.01158   -3.368  0.0365
  0.27445   -1.008  0.9976
 -0.32825   -6.113  <.0001
 -0.16142   -4.631  0.0002
```

```
 0.15650  -1.820  0.8072
 0.66361   2.528  0.3221
 0.37099   0.034  1.0000
 0.32346  -0.377  1.0000
 0.26475  -0.886  0.9993
 0.55292   1.443  0.9549
-0.05215  -3.740  0.0100
 0.11533  -2.255  0.5091
 0.85480   4.311  0.0010
 0.56156   1.816  0.8093
 0.51412   1.405  0.9629
 0.45457   0.902  0.9991
 0.74432   3.164  0.0683
 0.13734  -2.001  0.6933
 0.30590  -0.536  1.0000
 0.09526  -2.451  0.3717
 0.04877  -2.849  0.1597
-0.01032  -3.357  0.0378
 0.27569  -0.991  0.9979
-0.32734  -6.116  <.0001
-0.16017  -4.624  0.0002
 0.32722  -0.403  1.0000
 0.26882  -0.901  0.9991
 0.55467   1.390  0.9657
-0.04842  -3.697  0.0118
 0.11854  -2.246  0.5155
 0.31304  -0.498  1.0000
 0.60070   1.777  0.8308
-0.00360  -3.300  0.0453
 0.16379  -1.853  0.7880
 0.65513   2.260  0.5059
 0.04871  -2.830  0.1671
 0.21656  -1.380  0.9674
-0.19824  -4.952  <.0001
-0.03209  -3.534  0.0210
 0.52698   1.384  0.9668
```

Confidence level used: 0.95
Conf-level adjustment: tukey method for comparing a family of 12 estimates
P value adjustment: tukey method for comparing a family of 12 estimates

```r
emm_soln <- emmeans(fit1b, ~ job_category * solution, mode = "mean.class")
by_soln <- summary(
  pairs(emm_soln, by = "solution"),
  infer = TRUE # infer CIs
)

by_soln
```

```
solution = Computing environments:
 contrast                                                 estimate     SE  df
 Faculty - Postdocs and Staff Researchers                   0.0162 0.1690 Inf
 Faculty - Students                                        -0.4426 0.1460 Inf
 Faculty - (Non-research Staff)                             0.0287 0.1510 Inf
 Postdocs and Staff Researchers - Students                 -0.4588 0.1510 Inf
 Postdocs and Staff Researchers - (Non-research Staff)      0.0125 0.1560 Inf
 Students - (Non-research Staff)                            0.4713 0.1300 Inf
 asymp.LCL asymp.UCL z.ratio p.value
  -0.41851   0.45096   0.096  0.9997
  -0.81759  -0.06761  -3.032  0.0130
  -0.36044   0.41779   0.189  0.9976
  -0.84563  -0.07202  -3.047  0.0124
  -0.38818   0.41309   0.080  0.9998
   0.13648   0.80608   3.616  0.0017

solution = Publicity:
 contrast                                                 estimate     SE  df
 Faculty - Postdocs and Staff Researchers                  -0.2589 0.1720 Inf
 Faculty - Students                                        -0.3992 0.1910 Inf
 Faculty - (Non-research Staff)                             0.3004 0.1610 Inf
 Postdocs and Staff Researchers - Students                 -0.1403 0.1860 Inf
 Postdocs and Staff Researchers - (Non-research Staff)      0.5593 0.1550 Inf
 Students - (Non-research Staff)                            0.6995 0.1760 Inf
 asymp.LCL asymp.UCL z.ratio p.value
  -0.70076   0.18295  -1.505  0.4342
  -0.89016   0.09179  -2.089  0.1567
  -0.11266   0.71338   1.868  0.2418
  -0.61876   0.33820  -0.753  0.8753
   0.16068   0.95785   3.605  0.0018
   0.24709   1.15199   3.972  0.0004

solution = Containerization:
 contrast                                                 estimate     SE  df
```

```
Faculty - Postdocs and Staff Researchers                       0.0295 0.1750 Inf
Faculty - Students                                            -0.3647 0.2040 Inf
Faculty - (Non-research Staff)                                 0.1828 0.1610 Inf
Postdocs and Staff Researchers - Students                     -0.3942 0.2020 Inf
Postdocs and Staff Researchers - (Non-research Staff)   0.1533 0.1590 Inf
Students - (Non-research Staff)                                0.5475 0.1910 Inf
 asymp.LCL asymp.UCL z.ratio p.value
 -0.41974    0.47867    0.169  0.9983
 -0.88919    0.15970   -1.787  0.2797
 -0.23012    0.59573    1.137  0.6664
 -0.91444    0.12601   -1.947  0.2086
 -0.25449    0.56116    0.966  0.7688
  0.05807    1.03703    2.874  0.0211


solution = Documentation help:
 contrast                                                     estimate      SE  df
 Faculty - Postdocs and Staff Researchers                      -0.3236 0.1740 Inf
 Faculty - Students                                            -0.4665 0.1950 Inf
 Faculty - (Non-research Staff)                                -0.1626 0.1560 Inf
 Postdocs and Staff Researchers - Students                     -0.1429 0.1950 Inf
 Postdocs and Staff Researchers - (Non-research Staff)   0.1610 0.1570 Inf
 Students - (Non-research Staff)                                0.3039 0.1790 Inf
 asymp.LCL asymp.UCL z.ratio p.value
 -0.77003    0.12281   -1.862  0.2444
 -0.96672    0.03374   -2.396  0.0779
 -0.56278    0.23751   -1.044  0.7234
 -0.64440    0.35864   -0.732  0.8843
 -0.24117    0.56312    1.028  0.7328
 -0.15728    0.76499    1.693  0.3274


solution = A learning community:
 contrast                                                     estimate      SE  df
 Faculty - Postdocs and Staff Researchers                      -0.3525 0.1670 Inf
 Faculty - Students                                            -0.5588 0.1920 Inf
 Faculty - (Non-research Staff)                                -0.4885 0.1490 Inf
 Postdocs and Staff Researchers - Students                     -0.2064 0.1940 Inf
 Postdocs and Staff Researchers - (Non-research Staff)  -0.1360 0.1520 Inf
 Students - (Non-research Staff)                                0.0703 0.1790 Inf
 asymp.LCL asymp.UCL z.ratio p.value
 -0.78266    0.07774   -2.105  0.1515
 -1.05171   -0.06597   -2.913  0.0188
 -0.87073   -0.10627   -3.283  0.0057
 -0.70593    0.29316   -1.061  0.7131
```

```
 -0.52711    0.25503  -0.894  0.8081
 -0.38870    0.52939   0.394  0.9793
```

solution = Event planning:
```
 contrast                                                estimate     SE  df
 Faculty - Postdocs and Staff Researchers                 -0.3125 0.1730 Inf
 Faculty - Students                                       -0.5181 0.2030 Inf
 Faculty - (Non-research Staff)                           -0.0953 0.1560 Inf
 Postdocs and Staff Researchers - Students                -0.2056 0.2070 Inf
 Postdocs and Staff Researchers - (Non-research Staff)     0.2172 0.1610 Inf
 Students - (Non-research Staff)                           0.4228 0.1930 Inf
 asymp.LCL asymp.UCL z.ratio p.value
  -0.75643    0.13140  -1.809  0.2692
  -1.03880    0.00258  -2.556  0.0517
  -0.49591    0.30527  -0.611  0.9285
  -0.73614    0.32496  -0.996  0.7520
  -0.19658    0.63098   1.349  0.5319
  -0.07243    0.91801   2.193  0.1250
```

solution = Mentoring programs:
```
 contrast                                                estimate     SE  df
 Faculty - Postdocs and Staff Researchers                 -0.3554 0.1710 Inf
 Faculty - Students                                       -0.7545 0.1850 Inf
 Faculty - (Non-research Staff)                           -0.4148 0.1520 Inf
 Postdocs and Staff Researchers - Students                -0.3991 0.1920 Inf
 Postdocs and Staff Researchers - (Non-research Staff)    -0.0594 0.1610 Inf
 Students - (Non-research Staff)                           0.3397 0.1750 Inf
 asymp.LCL asymp.UCL z.ratio p.value
  -0.79593    0.08505  -2.073  0.1620
  -1.23068   -0.27839  -4.071  0.0003
  -0.80575   -0.02391  -2.726  0.0325
  -0.89328    0.09510  -2.075  0.1614
  -0.47255    0.35378  -0.369  0.9828
  -0.11114    0.79055   1.936  0.2131
```

solution = Education:
```
 contrast                                                estimate     SE  df
 Faculty - Postdocs and Staff Researchers                 -0.4016 0.1720 Inf
 Faculty - Students                                       -0.6624 0.1900 Inf
 Faculty - (Non-research Staff)                           -0.3755 0.1540 Inf
 Postdocs and Staff Researchers - Students                -0.2607 0.1940 Inf
 Postdocs and Staff Researchers - (Non-research Staff)     0.0262 0.1590 Inf
 Students - (Non-research Staff)                           0.2869 0.1780 Inf
```

```
asymp.LCL asymp.UCL z.ratio p.value
 -0.84346   0.04017  -2.335   0.0901
 -1.15080  -0.17394  -3.484   0.0028
 -0.77172   0.02077  -2.434   0.0707
 -0.75821   0.23676  -1.346   0.5332
 -0.38171   0.43405   0.165   0.9984
 -0.17097   0.74476   1.610   0.3730


solution = Legal support:
 contrast                                                estimate     SE  df
 Faculty - Postdocs and Staff Researchers                 -0.1794 0.1740 Inf
 Faculty - Students                                       -0.4676 0.1920 Inf
 Faculty - (Non-research Staff)                           -0.2507 0.1540 Inf
 Postdocs and Staff Researchers - Students                -0.2882 0.1960 Inf
 Postdocs and Staff Researchers - (Non-research Staff)    -0.0713 0.1590 Inf
 Students - (Non-research Staff)                           0.2169 0.1790 Inf
 asymp.LCL asymp.UCL z.ratio p.value
 -0.62577   0.26699  -1.032   0.7304
 -0.96010   0.02487  -2.439   0.0699
 -0.64634   0.14495  -1.628   0.3628
 -0.79171   0.21527  -1.471   0.4553
 -0.48084   0.33823  -0.447   0.9702
 -0.24234   0.67618   1.213   0.6183


solution = Industry partnerships:
 contrast                                                estimate     SE  df
 Faculty - Postdocs and Staff Researchers                 -0.1052 0.1780 Inf
 Faculty - Students                                       -0.4780 0.1800 Inf
 Faculty - (Non-research Staff)                            0.1976 0.1620 Inf
 Postdocs and Staff Researchers - Students                -0.3729 0.1830 Inf
 Postdocs and Staff Researchers - (Non-research Staff)     0.3028 0.1650 Inf
 Students - (Non-research Staff)                           0.6756 0.1670 Inf
 asymp.LCL asymp.UCL z.ratio p.value
 -0.56223   0.35190  -0.591   0.9348
 -0.93997  -0.01610  -2.659   0.0392
 -0.21882   0.61402   1.219   0.6147
 -0.84196   0.09623  -2.042   0.1726
 -0.12182   0.72734   1.832   0.2582
  0.24575   1.10551   4.038   0.0003


solution = Sustainability grants:
 contrast                                                estimate     SE  df
 Faculty - Postdocs and Staff Researchers                  0.0167 0.0952 Inf
```

```
Faculty - Students                                           -0.1616 0.0694 Inf
Faculty - (Non-research Staff)                                 0.3101 0.1130 Inf
Postdocs and Staff Researchers - Students                     -0.1784 0.0742 Inf
Postdocs and Staff Researchers - (Non-research Staff)          0.2934 0.1160 Inf
Students - (Non-research Staff)                                0.4718 0.0955 Inf
 asymp.LCL asymp.UCL z.ratio p.value
  -0.22773   0.26116   0.176  0.9981
  -0.33987   0.01658  -2.330  0.0913
   0.02077   0.59945   2.753  0.0301
  -0.36891   0.01219  -2.405  0.0762
  -0.00368   0.59047   2.537  0.0544
   0.22634   0.71718   4.938  <.0001

solution = Help finding funding:
 contrast                                                     estimate     SE  df
 Faculty - Postdocs and Staff Researchers                       0.0180 0.1290 Inf
 Faculty - Students                                            -0.1690 0.1160 Inf
 Faculty - (Non-research Staff)                                 0.3351 0.1340 Inf
 Postdocs and Staff Researchers - Students                     -0.1870 0.1190 Inf
 Postdocs and Staff Researchers - (Non-research Staff)          0.3171 0.1360 Inf
 Students - (Non-research Staff)                                0.5041 0.1240 Inf
 asymp.LCL asymp.UCL z.ratio p.value
  -0.31338   0.34942   0.140  0.9990
  -0.46788   0.12996  -1.452  0.4668
  -0.00848   0.67872   2.506  0.0590
  -0.49198   0.11802  -1.575  0.3930
  -0.03186   0.66607   2.334  0.0903
   0.18581   0.82235   4.069  0.0003

Confidence level used: 0.95
Conf-level adjustment: tukey method for comparing a family of 4 estimates
P value adjustment: tukey method for comparing a family of 4 estimates
```

Let's glance at the significant differences.

```
# Because there are so many significant comparisons,
# let's be stringent
sig_by_job <- subset(by_job, p.value < 0.0005)
sig_by_job
```

```
                                       contrast
5          Computing environments - Event planning
```

```
6        Computing environments - Mentoring programs
20               Publicity - Sustainability grants
29        Containerization - Sustainability grants
30          Containerization - Help finding funding
37     Documentation help - Sustainability grants
38     Documentation help - Help finding funding
44   A learning community - Sustainability grants
45   A learning community - Help finding funding
50          Event planning - Sustainability grants
51          Event planning - Help finding funding
55      Mentoring programs - Sustainability grants
56      Mentoring programs - Help finding funding
59               Education - Sustainability grants
60               Education - Help finding funding
62           Legal support - Sustainability grants
63           Legal support - Help finding funding
64   Industry partnerships - Sustainability grants
95        Containerization - Sustainability grants
96        Containerization - Help finding funding
110  A learning community - Sustainability grants
116         Event planning - Sustainability grants
117         Event planning - Help finding funding
121     Mentoring programs - Sustainability grants
122     Mentoring programs - Help finding funding
125              Education - Sustainability grants
128          Legal support - Sustainability grants
130  Industry partnerships - Sustainability grants
182         Event planning - Sustainability grants
200  Computing environments - Containerization
203  Computing environments - Event planning
218               Publicity - Sustainability grants
227        Containerization - Sustainability grants
228        Containerization - Help finding funding
248         Event planning - Sustainability grants
249         Event planning - Help finding funding
262  Industry partnerships - Sustainability grants
                    job_category     estimate        SE  df   asymp.LCL
5                        Faculty    0.6549404 0.1383278 Inf   0.2028847
6                        Faculty    0.6888481 0.1359182 Inf   0.2446670
20                       Faculty   -0.6897175 0.1246919 Inf  -1.0972112
29                       Faculty   -0.8326377 0.1244847 Inf  -1.2394542
30                       Faculty   -0.7008841 0.1312171 Inf  -1.1297021
37                       Faculty   -0.8863025 0.1220734 Inf  -1.2852387
```

```
38                         Faculty -0.7545489 0.1289687 Inf -1.1760190
44                         Faculty -1.0153942 0.1162150 Inf -1.3951852
45                         Faculty -0.8836407 0.1237773 Inf -1.2881454
50                         Faculty -1.1084421 0.1195653 Inf -1.4991821
51                         Faculty -0.9766886 0.1267895 Inf -1.3910373
55                         Faculty -1.1423498 0.1164505 Inf -1.5229105
56                         Faculty -1.0105963 0.1240400 Inf -1.4159595
59                         Faculty -1.0569497 0.1189241 Inf -1.4455941
60                         Faculty -0.9251962 0.1264674 Inf -1.3384922
62                         Faculty -0.8759528 0.1191070 Inf -1.2651948
63                         Faculty -0.7441992 0.1260213 Inf -1.1560374
64                         Faculty -0.6954577 0.1233462 Inf -1.0985536
95  Postdocs and Staff Researchers -0.8453910 0.1222004 Inf -1.2447424
96  Postdocs and Staff Researchers -0.7123321 0.1286174 Inf -1.1326544
110 Postdocs and Staff Researchers -0.6462254 0.1204395 Inf -1.0398220
116 Postdocs and Staff Researchers -0.7792098 0.1252404 Inf -1.1884959
117 Postdocs and Staff Researchers -0.6461509 0.1314915 Inf -1.0758656
121 Postdocs and Staff Researchers -0.7701944 0.1265056 Inf -1.1836151
122 Postdocs and Staff Researchers -0.6371354 0.1325076 Inf -1.0701709
125 Postdocs and Staff Researchers -0.6385922 0.1243440 Inf -1.0449489
128 Postdocs and Staff Researchers -0.6798460 0.1260943 Inf -1.0919226
130 Postdocs and Staff Researchers -0.5735799 0.1276135 Inf -0.9906213
182                       Students -0.7519809 0.1616113 Inf -1.2801274
200            Non-research Staff   0.5332636 0.1160426 Inf  0.1540358
203            Non-research Staff   0.5309440 0.1161705 Inf  0.1512982
218            Non-research Staff -0.6799672 0.1147994 Inf -1.0551319
227            Non-research Staff -0.7053335 0.1153851 Inf -1.0824125
228            Non-research Staff -0.5485665 0.1184652 Inf -0.9357112
248            Non-research Staff -0.7030140 0.1149538 Inf -1.0786835
249            Non-research Staff -0.5462469 0.1181389 Inf -0.9323254
262            Non-research Staff -0.5829469 0.1177207 Inf -0.9676586
    asymp.UCL   z.ratio       p.value
5   1.1069962  4.734699 1.388367e-04
6   1.1330292  5.068109 2.590106e-05
20 -0.2822239 -5.531373 2.076395e-06
29 -0.4258211 -6.688674 1.485164e-09
30 -0.2720661 -5.341408 6.000927e-06
37 -0.4873662 -7.260408 2.554301e-11
38 -0.3330789 -5.850638 3.215137e-07
44 -0.6356033 -8.737207 9.514611e-14
45 -0.4791360 -7.138956 6.212852e-11
50 -0.7177022 -9.270598 1.266764e-13
51 -0.5623399 -7.703227 9.453549e-13
```

```
55  -0.7617891 -9.809746 1.245670e-13
56  -0.6052330 -8.147340 1.683098e-13
59  -0.6683053 -8.887600 8.648637e-14
60  -0.5119001 -7.315688 1.697409e-11
62  -0.4867107 -7.354337 1.273992e-11
63  -0.3323611 -5.905344 2.311823e-07
64  -0.2923618 -5.638257 1.124693e-06
95  -0.4460396 -6.918070 3.021001e-10
96  -0.2920098 -5.538379 1.995309e-06
110 -0.2526288 -5.365562 5.254050e-06
116 -0.3699237 -6.221714 3.237886e-08
117 -0.2164362 -4.914013 5.710042e-05
121 -0.3567737 -6.088225 7.511344e-08
122 -0.2041000 -4.808292 9.681196e-05
125 -0.2322355 -5.135689 1.817081e-05
128 -0.2677695 -5.391570 4.550438e-06
130 -0.1565385 -4.494665 4.321159e-04
182 -0.2238344 -4.653021 2.057479e-04
200  0.9124913  4.595411 2.703628e-04
203  0.9105898  4.570384 3.040797e-04
218 -0.3048024 -5.923092 2.075892e-07
227 -0.3282546 -6.112865 6.439254e-08
228 -0.1614218 -4.630613 2.289050e-04
248 -0.3273444 -6.115621 6.329075e-08
249 -0.1601684 -4.623767 2.364616e-04
262 -0.1982351 -4.951948 4.711072e-05
```

```r
sig_by_soln <- subset(by_soln, p.value < 0.05)
sig_by_soln
```

```
                                              contrast              solution
2                            Faculty - Students Computing environments
4            Postdocs and Staff Researchers - Students Computing environments
6                     Students - (Non-research Staff) Computing environments
11 Postdocs and Staff Researchers - (Non-research Staff)            Publicity
12                     Students - (Non-research Staff)            Publicity
18                     Students - (Non-research Staff)       Containerization
26                            Faculty - Students    A learning community
27              Faculty - (Non-research Staff)    A learning community
38                            Faculty - Students       Mentoring programs
39              Faculty - (Non-research Staff)       Mentoring programs
44                            Faculty - Students              Education
```

```
56                                    Faculty - Students   Industry partnerships
60                   Students - (Non-research Staff)   Industry partnerships
63               Faculty - (Non-research Staff)   Sustainability grants
66               Students - (Non-research Staff)   Sustainability grants
72               Students - (Non-research Staff)    Help finding funding
      estimate          SE  df    asymp.LCL    asymp.UCL   z.ratio        p.value
2   -0.4425989 0.1459660 Inf -0.81759018 -0.06760760 -3.032205 1.297267e-02
4   -0.4588231 0.1505653 Inf -0.84563008 -0.07201615 -3.047337 1.236403e-02
6    0.4712768 0.1303217 Inf  0.13647631  0.80607726  3.616258 1.700432e-03
11   0.5592622 0.1551499 Inf  0.16067722  0.95784717  3.604658 1.776658e-03
12   0.6995423 0.1761166 Inf  0.24709308  1.15199158  3.972040 4.142473e-04
18   0.5475497 0.1905313 Inf  0.05806868  1.03703070  2.873804 2.113462e-02
26  -0.5588410 0.1918513 Inf -1.05171317 -0.06596874 -2.912885 1.878472e-02
27  -0.4884963 0.1487836 Inf -0.87072610 -0.10626660 -3.283268 5.661492e-03
38  -0.7545348 0.1853409 Inf -1.23068154 -0.27838811 -4.071064 2.732612e-04
39  -0.4148289 0.1521663 Inf -0.80574893 -0.02390883 -2.726155 3.249277e-02
44  -0.6623738 0.1901221 Inf -1.15080345 -0.17394418 -3.483940 2.780828e-03
56  -0.4780319 0.1798083 Inf -0.93996518 -0.01609858 -2.658564 3.924501e-02
60   0.6756306 0.1673319 Inf  0.24574967  1.10551161  4.037668 3.147720e-04
63   0.3101096 0.1126268 Inf  0.02076775  0.59945146  2.753426 3.006602e-02
66   0.4717569 0.0955300 Inf  0.22633727  0.71717647  4.938311 4.698058e-06
72   0.5040808 0.1238873 Inf  0.18581024  0.82235131  4.068864 2.758288e-04
```

Okay, so here, the "estimate" column shows the difference in estimated marginal means for the two levels of interest, holding the other factor level constant (of my two factors, job and solution). So when the contrast is Computing environments vs. A learning community, the job_category is Faculty, and the estimate is 0.57, this indicates that the difference between the estimates of faculty's average rating of computer environments and their average rating of a learning community is 0.56, on a three-point scale.

```
subset(summary(emm), job_category=="Faculty" & solution == "Computing environments")$mean.cl
```

```
[1] 0.5618926
```

Sustainability grants and Finding funding show up frequently as being significantly higher than some of the other solutions. Let's plot the distributions of responses for sustainability grants, as a sanity check.

```
grant_ratings <- grouped_bar_chart(
  df = subset(combined, solution=="Sustainability grants"),
  x_var = "job_category",
```

```
  fill_var = "utility",
  title = "Ratings for 'Sustainability grants'")
grant_ratings
```


Ratings for 'Sustainability grants'
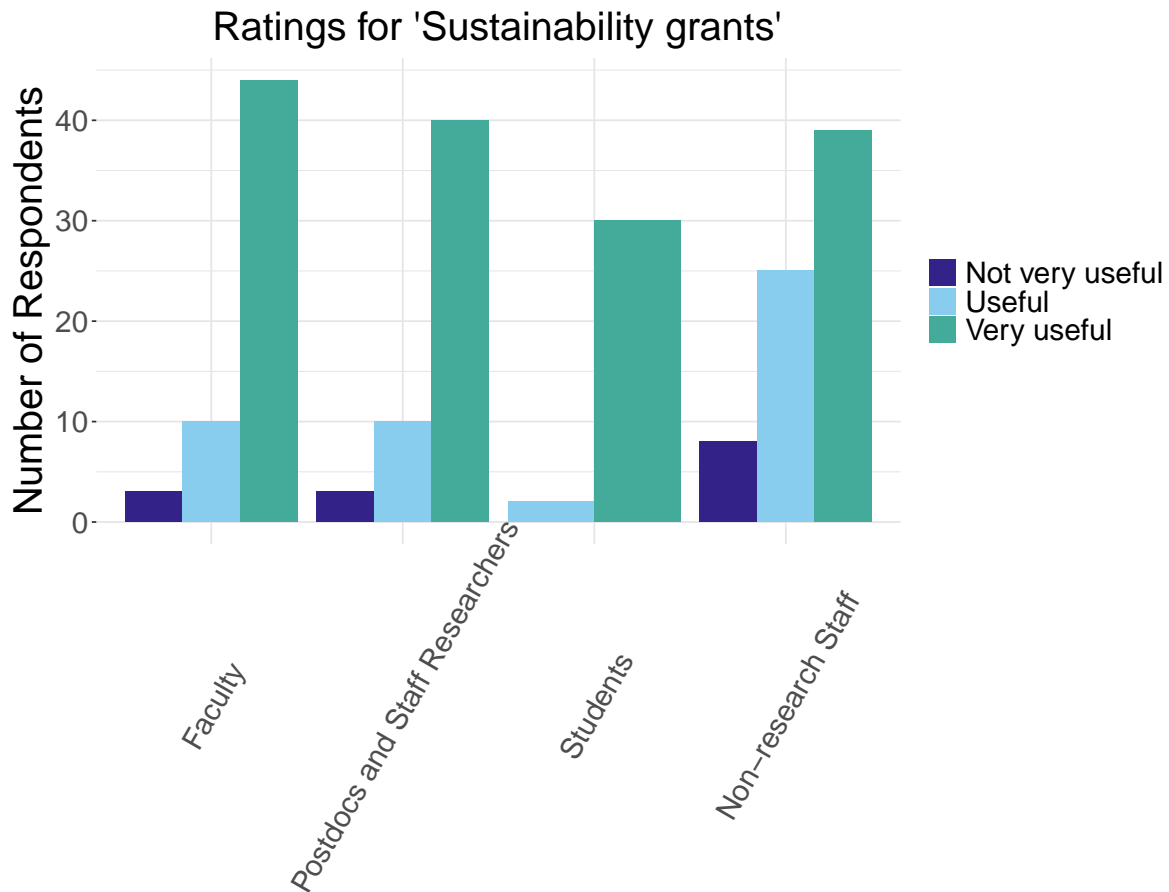
```
save_plot("solns_grants.tiff", 12, 10, p=grant_ratings)
```

Heat map (Unfinished/Abandoned)

I'd like to plot these data as a heat map. However, I find it really confusing to rely on the sign of the estimate (+/-) to tell me which solution is preferred. I'd rather have only positive values, and instead of using the sign to indicate which solution is preferred, we'll use the order of the solutions to indicate which solution is preferred. Let's say that the solution on the y-axis

is always the preferred solution, so that the color/value merely indicates the extent to which respondents prefer the solution on the y-axis.

To keep things simple for now, let's just look at non-research staff.

```
nr <- subset(by_job, job_category == "Non-research Staff")
nr$contrast <- as.character(nr$contrast)
soln1 <- unname(sapply(nr$contrast, function(x) strsplit(x, " - ")[[1]][1]))
soln2 <- unname(sapply(nr$contrast, function(x) strsplit(x, " - ")[[1]][2]))
nr2 <- data.frame(
  soln1 = soln1,
  soln2 = soln2,
  value = nr$estimate,
  pval = nr$p.value,
  significant = ifelse(nr$p.value < 0.05, "*", "")
)
head(nr2)
```

```
                   soln1                   soln2      value           pval
1 Computing environments              Publicity 0.50789719 0.0007100547
2 Computing environments         Containerization 0.53326357 0.0002703628
3 Computing environments      Documentation help 0.24148849 0.5740690917
4 Computing environments A learning community 0.04471831 0.9999997129
5 Computing environments           Event planning 0.53094399 0.0003040797
6 Computing environments      Mentoring programs 0.24534134 0.5797601732
  significant
1           *
2           *
3
4
5           *
6
```

```
nr2_clean <- nr2 %>%
  # if value < 0 swap soln1/soln2 and flip the sign--one step at a time
  mutate(
    soln_pref  = if_else(value < 0, soln2, soln1),   # preferred solution
    soln_other = if_else(value < 0, soln1, soln2),   # the other solution
    value_pos  = if_else(value < 0, -value, value)   # positive magnitude
  ) %>%

  # keep only the modified columns
```

```
  select(
    soln1 = soln_pref,
    soln2 = soln_other,
    value = value_pos,
    significant
  )

#Check the before and after
tail(nr2)
```

```
                 soln1                  soln2      value          pval
61          Legal support Industry partnerships  0.2677996 5.059041e-01
62          Legal support Sustainability grants -0.3151472 1.670945e-01
63          Legal support  Help finding funding -0.1583802 9.673988e-01
64 Industry partnerships Sustainability grants -0.5829469 4.711072e-05
65 Industry partnerships  Help finding funding -0.4261798 2.096520e-02
66 Sustainability grants  Help finding funding  0.1567670 9.667987e-01
   significant
61
62
63
64          *
65          *
66
```

```
tail(nr2_clean)
```

```
                 soln1                  soln2     value significant
61          Legal support Industry partnerships 0.2677996
62 Sustainability grants          Legal support 0.3151472
63  Help finding funding          Legal support 0.1583802
64 Sustainability grants Industry partnerships 0.5829469           *
65  Help finding funding Industry partnerships 0.4261798           *
66 Sustainability grants  Help finding funding 0.1567670
```

In this new data frame, soln1 is the preferred solution.

Let's reorder the factor levels and make them the same for both solution columns. This ensures that all solutions appear on both axes, in the same order.

```
sol_levels <- sort(unique(c(nr2_clean$soln1, nr2_clean$soln2)))

plot_df <- nr2_clean %>%
  mutate(
    soln1 = factor(soln1, levels = sol_levels),
    soln2 = factor(soln2, levels = sol_levels)
  ) %>%
  # complete fills in missing combinations
  # as new rows with NA values
  complete(soln1, soln2)

plot_df
```

```
# A tibble: 144 x 4
   soln1               soln2                    value significant
   <fct>               <fct>                    <dbl> <chr>
 1 A learning community A learning community    NA    <NA>
 2 A learning community Computing environments  NA    <NA>
 3 A learning community Containerization        0.489 "*"
 4 A learning community Documentation help      0.197 ""
 5 A learning community Education               0.155 ""
 6 A learning community Event planning          0.486 "*"
 7 A learning community Help finding funding    NA    <NA>
 8 A learning community Industry partnerships   0.366 ""
 9 A learning community Legal support           0.0984 ""
10 A learning community Mentoring programs      0.201 ""
# i 134 more rows
```

```
nr_heatmap <- ggplot(
  data = plot_df,
  aes(x = soln2, y = soln1, fill = value)
) +
  geom_tile(width = 0.97, height = 0.97) +   # gaps for the grid to show
  geom_text(aes(label = significant), color = "black", size = 8) +
  # Reverse x-axis order and put it on top
  scale_x_discrete(limits = rev(sol_levels), position = "top") +
  scale_fill_gradient(low = "white", high = "darkred", na.value = "#e6e6e6") +
  ggtitle("Solutions preferred by non-research staff") +
  labs(
    fill = "Extent to which\ny-axis solution is\npreferred (difference in\nestimated mean rat
  ) +
```

```
  theme(
    axis.title.x = element_blank(),
    axis.title.y = element_blank(),
    axis.text.x = element_text(
      angle = 46,
      vjust = 0,
      hjust = 0,
      size = 20
    ),
    axis.text.y = element_text(size = 20),
    axis.ticks.x = element_blank(),
    axis.ticks.y = element_blank(),
    legend.title = element_text(size = 15),
    panel.background = element_blank(),
    panel.grid = element_line(linetype = "solid", color = "gray90"),
    plot.title = element_text(
      hjust = 0.5,
      size = 24,
      margin = margin(b = 15)
    ),
    plot.margin = unit(c(0.3, 0.3, 0.3, 0.3), "cm")
  )

#nr_heatmap
```

Presumably, those warnings are just because our data frame contains a bunch of NA values, for combinations where the x-axis solution is preferred, and so we have no data.

```
save_plot("solns_heatmap_nrstaff.tiff", 12, 10, p=nr_heatmap)
```

```
Warning: Removed 78 rows containing missing values or values outside the scale range
(`geom_text()`).
```

I'd like to "validate" this result by eyeballing a plot of the number of "Not very useful", "Useful", and "Very useful" results for non-research staff for a couple of solutions, say, sustainability grants and a learning community. The "favorite" solution question suggested that a learning community was more popular than grants among research staff, so the result here, which suggests grants are the most popular solution, is somewhat surprising.

```
t <- long_data %>%
  filter(job_category == "Non-research Staff") %>%
  filter(solution == "Computing environments" |
         solution == "A learning community" |
         solution == "Sustainability grants" |
         solution == "Publicity")
```

```
gbc <- grouped_bar_chart(
  df = t,
  x_var = "solution",
  fill_var = "utility",
  title = "Non-research staff solution preferences")

gbc
```

Non−research staff solution preferences
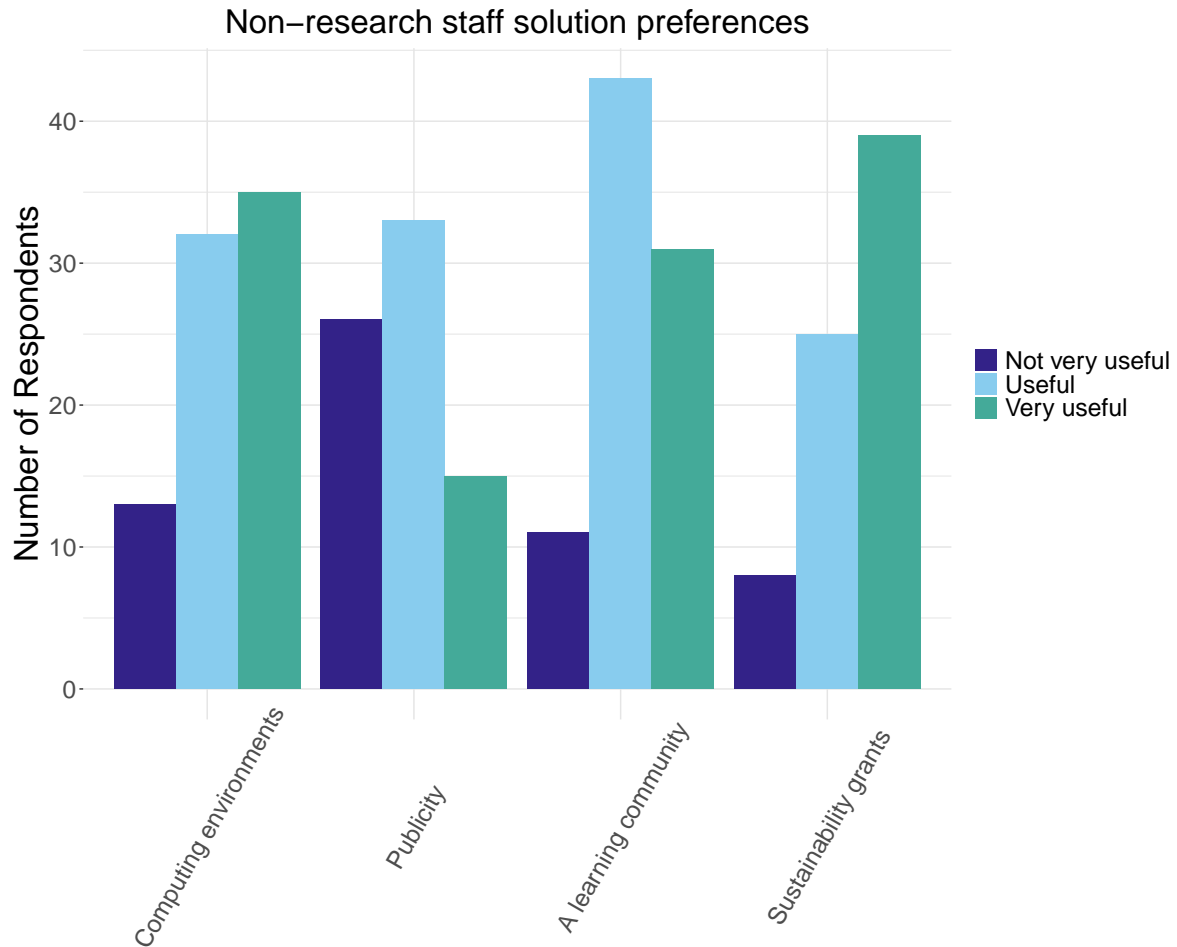

```
save_plot("solns_sanity_check_nrstaff.tiff", 12, 10, p=gbc)
```

This looks reasonably consistent with the model. From this bar chart, only Sustainability grants and Computing environments have a strong, linear slope with "very useful" being the most common response; and of the two, that trend is more pronounced for Sustainability grants. Previously, I found that "A learning community" was the number 1 solution from non-research staff when we asked them to choose their top solution (see solutions_plots.qmd), but apparently when they were allowed to rate solutions on a Likert scale, Sustainability grants was more popular, basically.

This plot is pretty complicated and convoluted. If I do want to publish it, I'll probably want to use a diverging color scheme for positive and negative differences, and keep only squares on the diagonal gray.

Session Info

```
sessionInfo()
```

```
R version 4.4.2 (2024-10-31)
Platform: aarch64-apple-darwin20
Running under: macOS Sequoia 15.6

Matrix products: default
BLAS:   /Library/Frameworks/R.framework/Versions/4.4-arm64/Resources/lib/libRblas.0.dylib
LAPACK: /Library/Frameworks/R.framework/Versions/4.4-arm64/Resources/lib/libRlapack.dylib;

locale:
[1] en_US.UTF-8/en_US.UTF-8/en_US.UTF-8/C/en_US.UTF-8/en_US.UTF-8

time zone: America/Los_Angeles
tzcode source: internal

attached base packages:
[1] tools     stats     graphics  grDevices datasets  utils     methods
[8] base

other attached packages:
 [1] treemap_2.4-4        tidyr_1.3.1          stringr_1.5.1
 [4] scales_1.4.0         readr_2.1.5          pwr_1.3-0
 [7] patchwork_1.3.0      ordinal_2023.12-4.1  mvabund_4.2.1
[10] languageserver_0.3.16 here_1.0.1          gtools_3.9.5
[13] fpc_2.2-13           forcats_1.0.0        factoextra_1.0.7
[16] ggplot2_3.5.2        emmeans_1.11.1       dplyr_1.1.4
[19] corrplot_0.95        cluster_2.1.8.1

loaded via a namespace (and not attached):
 [1] tidyselect_1.2.1    gridBase_0.4-7      farver_2.1.2
 [4] fastmap_1.2.0       promises_1.3.3      digest_0.6.37
 [7] mime_0.13           estimability_1.5.1  lifecycle_1.0.4
[10] statmod_1.5.0       processx_3.8.6      magrittr_2.0.3
[13] kernlab_0.9-33      compiler_4.4.2      rlang_1.1.6
[16] utf8_1.2.5          igraph_2.1.4        yaml_2.3.10
[19] data.table_1.17.6   knitr_1.50          labeling_0.4.3
[22] mclust_6.1.1        xml2_1.3.8          RColorBrewer_1.1-3
[25] withr_3.0.2         purrr_1.0.4         numDeriv_2016.8-1.1
```

```
[28] nnet_7.3-19        grid_4.4.2          stats4_4.4.2
[31] xtable_1.8-4       colorspace_2.1-1    MASS_7.3-61
[34] prabclus_2.3-4     cli_3.6.5           mvtnorm_1.3-3
[37] rmarkdown_2.29     generics_0.1.4      robustbase_0.99-4-1
[40] tzdb_0.5.0         modeltools_0.2-24   parallel_4.4.2
[43] vctrs_0.6.5        Matrix_1.7-1        jsonlite_2.0.0
[46] callr_3.7.6        hms_1.1.3           ggrepel_0.9.6
[49] diptest_0.77-1     tweedie_2.3.5       glue_1.8.0
[52] DEoptimR_1.1-3-1   ps_1.9.1            stringi_1.8.7
[55] gtable_0.3.6       later_1.4.2         tibble_3.2.1
[58] pillar_1.10.2      htmltools_0.5.8.1   R6_2.6.1
[61] ucminf_1.2.2       rprojroot_2.0.4     evaluate_1.0.3
[64] shiny_1.11.0       lattice_0.22-6      renv_1.1.4
[67] httpuv_1.6.16      class_7.3-22        Rcpp_1.0.14
[70] flexmix_2.3-20     nlme_3.1-166        xfun_0.52
[73] pkgconfig_2.0.3
```