Introduction to Mixture Models - Enumeration & Plotting

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Norwegian University of Science and Technology - A Course in `MplusAutomation`

June 01, 2021

Latent Class Analysis (LCA)

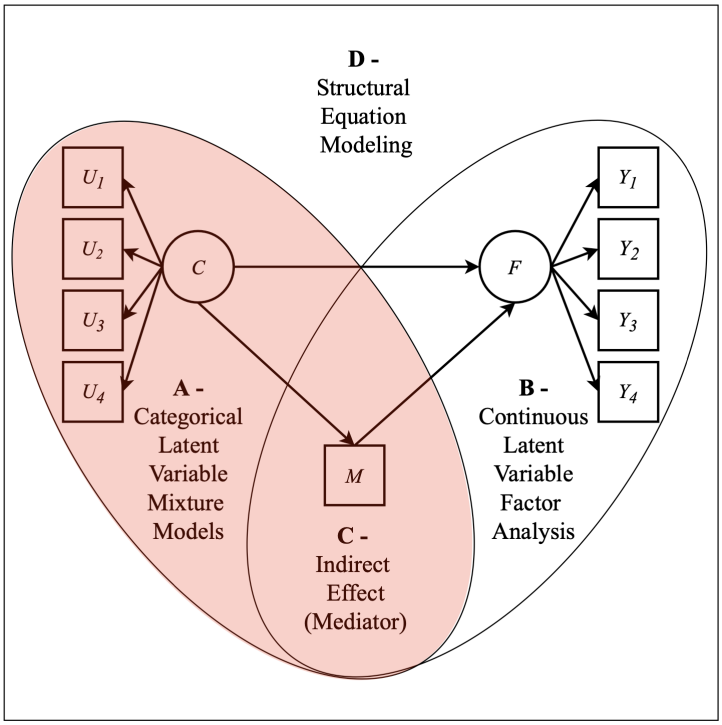

Figure. Picture has been adapted from study by Múthen, 2006.

Lab preparation

Data source:

1. The first example utilizes a dataset on undergraduate *Cheating* available from the `poLCA` package (Dayton, 1998): See documentation here
2. The second examples utilizes the public-use dataset, *The Longitudinal Survey of American Youth* (**LSAY**): See documentation here
3. The third examples utilizes the *Kindergarten Student Entrance Profile* (**KSEP**) (Quirk et al., 2011): See documentation here

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Load packages

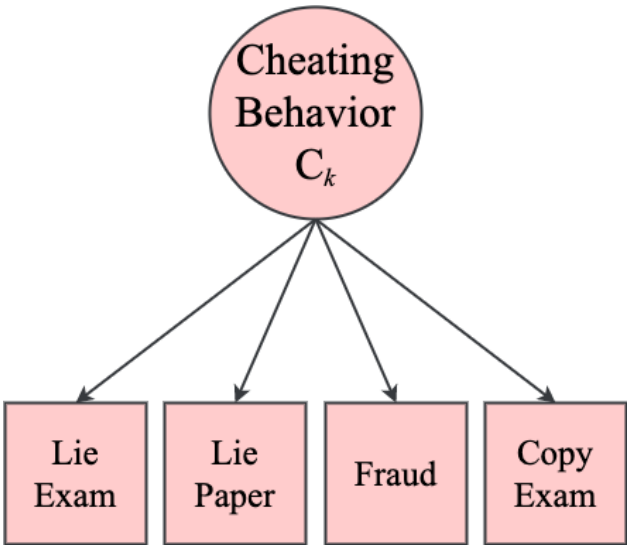
```
library(tidyverse)
library(haven)
library(glue)
library(MplusAutomation)
library(here)
library(janitor)
library(gt)
library(semPlot)
library(reshape2)
library(cowplot)
library(poLCA)
```

Enumerate and plot mixtures

Compare k-class models 1 through 6

Example 1: Undergraduate Cheating behavior

"Dichotomous self-report responses by 319 undergraduates to four questions about cheating behavior" (poLCA, 2016).



LCA indicators[1]

Name	Label	Values
LieExam	lied to avoid taking an exam	0 = No, 1 = Yes
LiePaper	lied to avoid handing a term paper in on time	0 = No, 1 = Yes
Fraud	purchased a term paper to hand in as their own or ...	0 = No, 1 = Yes
CopyExam	copied answers during an exam from someone sitting near to them	0 = No, 1 = Yes

[1]Undergraduate Cheating Behavior

Prepare data

```
data(cheating)

cheating <- cheating %>% clean_names()

df_cheat <-  cheating %>%
  dplyr::select(1:4) %>%
  dplyr::mutate_all(funs(.-1))
```

Run a quick LCA

```
lca_k1_4  <- lapply(1:4, function(k) {
  lca_enum  <- mplusObject(

    TITLE = glue("Class {k}"),

    VARIABLE = glue(
    "categorical = lieexam-copyexam;
     usevar = lieexam-copyexam;
     classes = c({k}); "),

  ANALYSIS =
   "estimator = mlr;
    type = mixture;
```

```
    starts = 200 100;
    processors = 10;",

  OUTPUT = "tech11 tech14;",

  PLOT =
    "type = plot3;
    series = lieexam-copyexam(*);",

  usevariables = colnames(df_cheat),
  rdata = df_cheat)

lca_enum_fit <- mplusModeler(lca_enum,
                             dataout=glue(here("19-intro-mixtures", "enum_cheat", "lca_cheat.dat")),
                             modelout=glue(here("19-intro-mixtures", "enum_cheat", "c{k}_lca_cheat.inp")),
                             check=TRUE, run = TRUE, hashfilename = FALSE)
})
```

View model fit statistics with `mixtureSummaryTable()`

```
output_cheat <- readModels(here("19-intro-mixtures", "enum_cheat"), quiet = TRUE)
```

```
## <simpleError in startLine:endLine: NA/NaN argument>
## <simpleError in startLine:endLine: NA/NaN argument>
## <simpleError in startLine:endLine: NA/NaN argument>
```

```
enum_summary <- LatexSummaryTable(output_cheat,
                keepCols=c("Title", "LL", "BIC", "aBIC",
                           "BLRT_PValue", "T11_VLMR_PValue"),
                sortBy = "Title")

enum_summary %>%
  gt() %>%
  tab_header(
    title = "Fit Indices",
    subtitle = md(" ")) %>%
  cols_label(
   Title = "Classes",
   LL = md("*LL*"),
   BLRT_PValue = html("BLRT"),
   T11_VLMR_PValue = html("VLMR")) %>%
  tab_options(
    table.width = pct(80)) %>%
  tab_footnote(
    footnote = "Undergraduate Cheating Behavior",
    location = cells_title())
```

Fit Indices[1]

Classes	*LL*	BIC	aBIC	BLRT	VLMR
Class 1	-467.438	957.937	945.250	NA	NA
Class 2	-440.027	931.941	903.395	0.0000	0.0000

Class 3	-436.236	953.184	908.779	0.1395	0.1656
Class 4	-436.145	981.829	921.564	1.0000	0.6868

[1]Undergraduate Cheating Behavior

Extract and prepare plot data

```
# extract posterior probabilities
plot1 <- as.data.frame(output_cheat[["c4_lca_cheat.out"]]
                           [["gh5"]][["means_and_variances_data"]]
                           [["estimated_probs"]][["values"]]
                           [seq(2, 8, 2),]) #seq("from","to","by")

# extract class size proportions
c_size <- as.data.frame(output_cheat[["c4_lca_cheat.out"]]
                        [["class_counts"]][["modelEstimated"]][["proportion"]])

colnames(c_size) <- paste0("cs")

c_size <- c_size %>% mutate(cs = round(cs*100, 2))

#rename columns (classes) and "Var" (indicator names)
colnames(plot1) <- paste0("C", 1:4, glue(" ({c_size[1:4,]}%)"))
plot1 <- cbind(Var = paste0("U", 1:4), plot1)

# choose the order of indicators by changing to ordered factor
plot1$Var <- fct_inorder(plot1$Var)

#change dateframe from wide to long format
pd_long1 <- melt(plot1, id.vars = "Var")
```

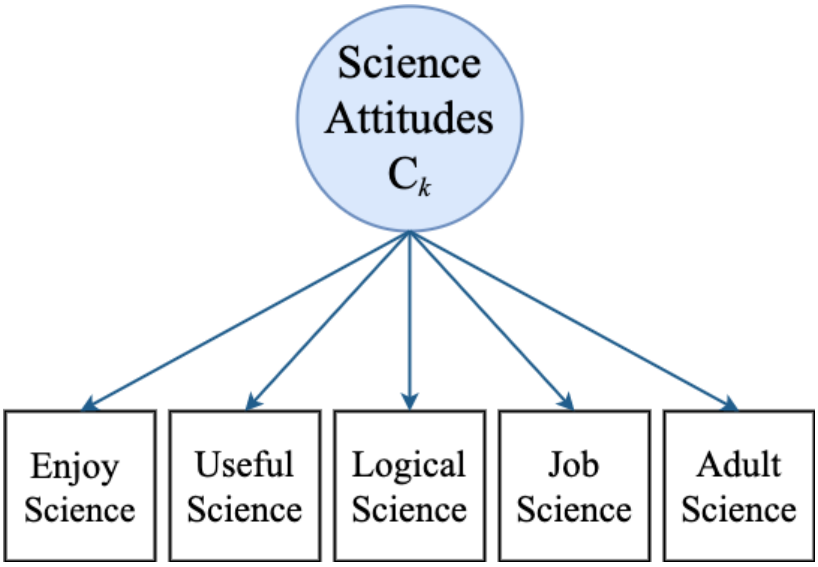
Plot 4-class latent class posterior probability plot

```
ggplot(pd_long1, aes(Var, value, shape = variable,
                     colour = variable, lty = variable)) +
  geom_point(size = 4) + geom_line(aes(as.integer(Var))) +
  scale_x_discrete(labels = c("Lie Exam", "Lie Paper", "Fraud", "Copy Exam")) +
  scale_y_continuous("Probability") +
  scale_colour_viridis_d(end = .7) +
  theme_cowplot() + labs(x=" ") +
  theme(text=element_text( size=12),
        legend.key.width = unit(.5, "line"),
        legend.text = element_text( size=12),
        legend.title = element_blank(),
        legend.position = "top")
```

save figure

```
ggsave(here("19-intro-mixtures", "figures", "C4_Cheat_LCA_Plot.png"), dpi="retina", height=5, width=7, u
```

Example 2: Longitudinal Study of American Youth, Science Attitudes



Load data

```
lsay_data <- read_csv("https://garberadamc.github.io/project-site/data/lca_lsay_sci.csv",
                      na = c("9999", "9999.00")) %>%
  clean_names() %>%
  dplyr::select(1:5, Enjoy = ab39m, Useful = ab39t,
                    Logical = ab39u, Job = ab39w, Adult = ab39x)
```

View LCA indicators

LCA Indicators[1]

Name	Label	Values
Enjoy	I enjoy science	0 = Disagree, 1 = Agree
Useful	Science useful in everday problems	0 = Disagree, 1 = Agree
Logical	Science helps logical thinkng	0 = Disagree, 1 = Agree
Job	Need science for a good job	0 = Disagree, 1 = Agree
Adult	Will use science often as an adult	0 = Disagree, 1 = Agree

[1]Longitudinal Study of American Youth

Run enumeration using `mplusObject` method

```
lca_k1_6  <- lapply(1:6, function(k) {
  lca_enum  <- mplusObject(

    TITLE = glue("Class {k}"),

    VARIABLE = glue(
    "categorical = Enjoy-Adult;
     usevar = Enjoy-Adult;
```

```
    classes = c({k}); "),

  ANALYSIS =
   "estimator = mlr;
    type = mixture;
    starts = 200 100;
    processors = 10;",

  OUTPUT = "sampstat residual tech11 tech14;",

  PLOT =
    "type = plot3;
    series = Enjoy-Adult(*);",

  usevariables = colnames(lsay_data),
  rdata = lsay_data)

lca_enum_fit <- mplusModeler(lca_enum,
                             dataout=glue(here("19-intro-mixtures", "enum_lsay", "lca_lsay.dat")),
                             modelout=glue(here("19-intro-mixtures", "enum_lsay", "c{k}_lca.inp")) ,
                             check=TRUE, run = TRUE, hashfilename = FALSE)
})
```

Compare model fit for series of enumerated models

```
all_output <- readModels(here("19-intro-mixtures", "enum_lsay"),  quiet = TRUE)
```

```
## <simpleError in startLine:endLine: NA/NaN argument>
## <simpleError in startLine:endLine: NA/NaN argument>
## <simpleError in startLine:endLine: NA/NaN argument>
## <simpleError in startLine:endLine: NA/NaN argument>
## <simpleError in startLine:endLine: NA/NaN argument>
```

```
enum_summary <- LatexSummaryTable(all_output,
                keepCols=c("Title", "LL", "BIC", "aBIC",
                           "BLRT_PValue", "T11_VLMR_PValue"),
                sortBy = "Title")

gt(enum_summary)  %>%
  tab_header(
    title = "Fit Indices",
    subtitle = md(" ")) %>%
  cols_label(
    Title = "Classes",
    LL = md("*LL*"),
    BLRT_PValue = html("BLRT"),
    T11_VLMR_PValue = html("VLMR")) %>%
  tab_options(
    table.width = pct(80)) %>%
  tab_footnote(
    footnote = "Longitudinal Study of American Youth",
    location = cells_title())
```

Fit Indices[1]

Classes	*LL*	BIC	aBIC	BLRT	VLMR
Class 1	-10250.604	20541.34	20525.45	NA	NA
Class 2	-8785.317	17658.92	17623.97	0.0000	0.0000
Class 3	-8693.569	17523.59	17469.57	0.0000	0.0000
Class 4	-8664.090	17512.79	17439.71	0.0000	0.0000
Class 5	-8662.386	17557.54	17465.40	1.0000	0.6736
Class 6	-8661.541	17604.01	17492.80	0.6667	0.7884

[1]Longitudinal Study of American Youth

Compare probability plots for $K = 1 : 6$ class solutions

```
# for (i in 1:length(all_output)) {
#   temp <- all_output[[i]]$parameters$unstandardized
#   temp <- data.frame(unclass(temp)) %>%
#     mutate(model = paste0(i, "-Class Model"))
#   model_results <- rbind(model_results, temp)
# }
#
# model_results <- model_results %>%
#   filter(paramHeader == "Thresholds") %>%
#   dplyr::select(est, model, LatentClass, param) %>%
#   mutate(prob = (1 / (1 + exp(est))))
#
# ggplot(model_results, aes(x = param, y = prob,
#            color = LatentClass,
#            shape = LatentClass,
#            group = LatentClass,
#            lty = LatentClass)) +
#   geom_point() + geom_line() +
#   facet_wrap(~ model, ncol = 2) +
#   labs(title = "LCA Posterior Probability Plot",
#        x= "Science attitudes", y = "Probability") +
#   theme_minimal()
```

Example 3 - Kindergarten Student Entrance Profile (KSEP)

```
ksep <- read_csv("https://garberadamc.github.io/project-site/data/ksep_sub_18.csv")
```

LCA Indicators[1]

Name	Label	Values
seek_hlp	Seeks adult help when appropriate	0 = Not Mastered, 1 = Mastered
cooperat	Engages in cooperative play activities with peers	0 = Not Mastered, 1 = Mastered
imp_cntr	Exhibits impulse control and self-regulation	0 = Not Mastered, 1 = Mastered

repeats	Stays with or repeats a task	0 = Not Mastered, 1 = Mastered
separate	Separates appropriately from caregiver most days	0 = Not Mastered, 1 = Mastered
new_activ	Is enthusiastic and curious in approaching new activities	0 = Not Mastered, 1 = Mastered
folw_rul	Follows rules when participating in routine activities	0 = Not Mastered, 1 = Mastered
name	Recognizes own name	0 = Not Mastered, 1 = Mastered
writes	Writes own name	0 = Not Mastered, 1 = Mastered
express	Demonstrates expressive abilities	0 = Not Mastered, 1 = Mastered
quantity	Understands that numbers represent quantity	0 = Not Mastered, 1 = Mastered
colors	Recognizes Colors	0 = Not Mastered, 1 = Mastered
shapes	Recognizes primary shapes	0 = Not Mastered, 1 = Mastered

[1]Kindergarten Student Entrance Profile

Enumeration: Compare k-class models 1-6

```
lca_k1_6  <- lapply(1:6, function(k) {
  lca_enum  <- mplusObject(

    TITLE = glue("Class {k}"),

    VARIABLE = glue(
    "categorical = seek_hlp-shapes;
     usevar = seek_hlp-shapes;
     classes = c({k}); "),

  ANALYSIS =
   "estimator = mlr;
    type = mixture;
    stseed = 5212020;
    starts = 200 100;
    processors = 10;",

  OUTPUT = "sampstat residual tech11 tech14;",

  PLOT =
    "type = plot3;
    series = seek_hlp-shapes(*);",

  usevariables = colnames(ksep),
  rdata = ksep)

lca_enum_fit <- mplusModeler(lca_enum,
                             dataout=glue(here("19-intro-mixtures", "enum_ksep", "lca_ksep.dat")),
                             modelout=glue(here("19-intro-mixtures", "enum_ksep", "c{k}_lca_ksep.inp"))
                             check=TRUE, run = TRUE, hashfilename = FALSE)
})
```

Compare model fit for series of enumerated models

```
all_output <- readModels(here("19-intro-mixtures", "enum_ksep"), quiet = TRUE)
```

```
## <simpleError in startLine:endLine: NA/NaN argument>
## <simpleError in startLine:endLine: NA/NaN argument>
```

```
## <simpleError in startLine:endLine: NA/NaN argument>
## <simpleError in startLine:endLine: NA/NaN argument>
## <simpleError in startLine:endLine: NA/NaN argument>
```

```
enum_summary <- LatexSummaryTable(all_output,
                keepCols=c("Title", "LL", "BIC", "aBIC",
                           "BLRT_PValue", "T11_VLMR_PValue"),
                sortBy = "Title")

gt(enum_summary) %>%
  tab_header(
    title = "Fit Indices",
    subtitle = md(" ")) %>%
  cols_label(
    Title = "Classes",
    LL = md("*LL*"),
    BLRT_PValue = html("BLRT"),
    T11_VLMR_PValue = html("VLMR")) %>%
  tab_options(
    table.width = pct(80)) %>%
  tab_footnote(
    footnote = "Kindergarten Student Entrance Profile",
    location = cells_title())
```

Fit Indices[1]

Classes	*LL*	BIC	aBIC	BLRT	VLMR
Class 1	-11844.461	23783.62	23742.32	NA	NA
Class 2	-9712.793	19622.26	19536.49	0	0.0000
Class 3	-9372.043	19042.74	18912.49	0	0.0000
Class 4	-9215.475	18831.58	18656.86	0	0.1240
Class 5	-9137.866	18778.34	18559.15	0	0.0722
Class 6	-9075.565	18755.71	18492.05	0	0.0394

[1]Kindergarten Student Entrance Profile

Compare probability plots for $K = 1 : 6$ class solutions

```
# for (i in 1:length(all_output)) {
#   temp <- all_output[[i]]$parameters$unstandardized
#   temp <- data.frame(unclass(temp)) %>%
#     mutate(model = paste0(i, "-Class Model"))
#   model_results <- rbind(model_results, temp)
# }
#
# model_results <- model_results %>%
#   filter(paramHeader == "Thresholds") %>%
#   dplyr::select(est, model, LatentClass, param) %>%
#   mutate(prob = (1 / (1 + exp(est))))
#
# ggplot(model_results, aes(x = param, y = prob,
#            color = LatentClass, shape = LatentClass,
#            group = LatentClass, lty = LatentClass)) +
```

```
#   geom_point() + geom_line() +
#   scale_colour_viridis_d() +
#   facet_wrap(~ model, ncol = 2) +
#   labs(title = "Kindergarten Student Entrance Profile (KSEP)",
#        x= " ", y = "Probability") +
#   scale_x_discrete(labels =
#     c("Seeks help", "Cooperative", "Impulse control","Repeats", "Separates",
#       "New activities", "Follows rules", "Name", "Writes", "Expressive", "Quantity",
#       "Colors", "Shapes")) +
#   theme_minimal() + theme(panel.grid.major.y = element_blank(),
#                           axis.text.x = element_text(angle = -45, hjust = -.1))
```

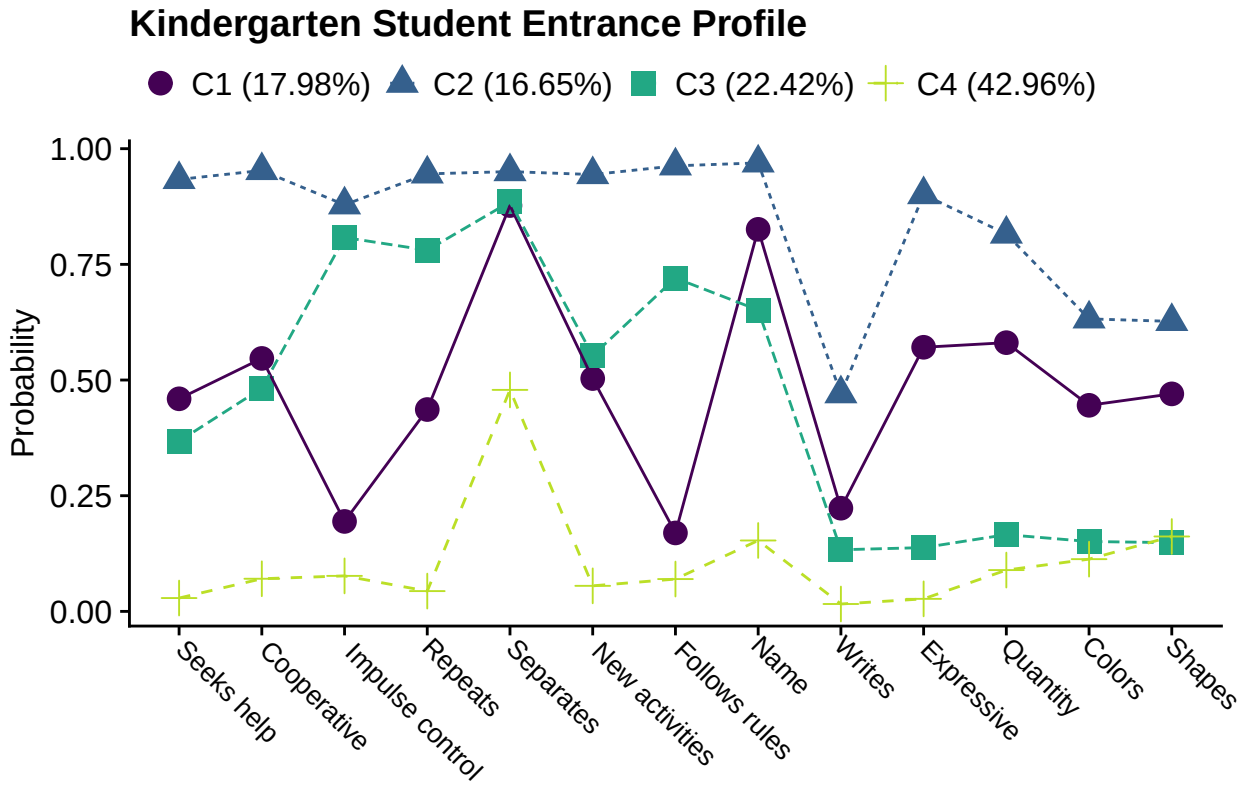
Extraxt and prepare plot data

```
# extract posterior probabilities
plot1 <- as.data.frame(all_output[["c4_lca_ksep.out"]]
                           [["gh5"]][["means_and_variances_data"]]
                           [["estimated_probs"]][["values"]]
                           [seq(2, 26, 2),]) #seq("from","to","by")

# extract class size proportions
c_size <- as.data.frame(all_output[["c4_lca_ksep.out"]]
                        [["class_counts"]][["modelEstimated"]][["proportion"]])

colnames(c_size) <- paste0("cs")

c_size <- c_size %>% mutate(cs = round(cs*100, 2))

#rename columns (classes) and "Var" (indicator names)
colnames(plot1) <- paste0("C", 1:4, glue(" ({c_size[1:4,]}%)"))
plot1 <- cbind(Var = paste0("U", 1:13), plot1)

# choose the order of indicators by changing to ordered factor
plot1$Var <- fct_inorder(plot1$Var)

#change dateframe fromw wide to long format
pd_long1 <- melt(plot1, id.vars = "Var")
```

Plot 4-class mixture

```
ggplot(pd_long1, aes(Var, value, shape = variable,
                     colour = variable, lty = variable)) +
  geom_point(size = 4) + geom_line(aes(as.integer(Var))) +
  scale_x_discrete(labels = c("Seeks help", "Cooperative", "Impulse control", "Repeats",
                              "Separates", "New activities", "Follows rules", "Name",
                              "Writes", "Expressive", "Quantity", "Colors", "Shapes")) +
  scale_y_continuous("Probability") +
  scale_colour_viridis_d(end = .9) +
  labs(title="Kindergarten Student Entrance Profile", x=" ") +
  theme_cowplot() +
  theme(text=element_text( size=12),
       legend.key.width = unit(.5, "line"),
       legend.text = element_text( size=12),
```

```
      legend.title = element_blank(),
      axis.text.x = element_text(angle = -45, hjust = -.1, size=10),
      legend.position = "top")
```




```
ggsave(here("19-intro-mixtures", "figures","Class4_KSEP_LCA_plot.png"),
       dpi=300, height=4, width=6, units="in")
```

References

Drew A. Linzer, Jeffrey B. Lewis (2011). poLCA: An R Package for Polytomous Variable Latent Class Analysis. Journal of Statistical Software, 42(10), 1-29. URL http://www.jstatsoft.org/v42/i10/.

Hallquist, M. N., & Wiley, J. F. (2018). MplusAutomation: An R Package for Facilitating Large-Scale Latent Variable Analyses in Mplus. Structural equation modeling: a multidisciplinary journal, 25(4), 621-638.

Miller, J. D., Hoffer, T., Suchner, R., Brown, K., & Nelson, C. (1992). LSAY codebook. Northern Illinois University.

Muthén, B. O., Muthén, L. K., & Asparouhov, T. (2017). Regression and mediation analysis using Mplus. Los Angeles, CA: Muthén & Muthén.

Muthén, L.K. and Muthén, B.O. (1998-2017). Mplus User's Guide. Eighth Edition. Los Angeles, CA: Muthén & Muthén

Quirk, M., Furlong, M., Lilles, E., Felix, E., & Chin, J. (2011). Preliminary development of a kindergarten school readiness assessment for Latino students. Journal of Applied School Psychology, 27(1), 77-102.

R Core Team (2017). R: A language and environment for statistical computing. R Foundation for Statistical Computing, Vienna, Austria. URL http://www.R-project.org/

Wickham et al., (2019). Welcome to the tidyverse. Journal of Open Source Software, 4(43), 1686, https://doi.org/10.21105/joss.01686